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# THE HOUSE OF LIFE

## Human Physiology

WITH ITS APPLICATIONS TO THE PRESERVATION OF HEALTH

*FOR USE IN CLASSES AND POPULAR READING*

BY

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J. NEWLANDS, ESQ., F.C.S.

## I Inscribe my Thanks upon this Page

For the knowledge which they first opened to me, and for the work which they did in the medical education of women at a time (1864-72) when high disinterested courage was shown in giving such teaching.

FLORENCE FENWICK MILLER.

LONDON, 1878.

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# THE HOUSE OF LIFE

# PREFACE.

NUMEROUS as are the works that have been published upon Elementary Physiology and upon Hygiene, as separate subjects, I am not aware that one exists at all resembling this volume, either in intention or arrangement. Indeed, I have been partly induced to write this little work by feeling the want of such an one to recommend for reading, when I have been lecturing to public audiences, or teaching classes of women in this subject. The distinctive feature of this book is that it not only treats of physiology, but, at the same moment, of health: its science is sufficiently full and precise to make it a suitable text-book for classes and students (whether preparing for the South Kensington first-stage examination or not), while at the same time the practical application of that science is everywhere shown, and the long preservation of a healthy life is taught by and through the structure of the House of Life. I am convinced that for popular study (that is to say,

always, *except* in preparation for the medical profession) Physiology and Hygiene should be treated of together, and as related to each other. I am fully alive to the value of the study of any science, as a mental discipline; but, at the same time, I believe that physiology is far above all other sciences as a subject that every person (and especially every woman) ought to obtain some knowledge of, just because it can be turned to so important a use in daily life—because the widespread knowledge of it will aid sanitation, and by making our people more healthy, will likewise make them more noble and more happy.

The Pronouncing Index is also a special feature, and is intended for the benefit of those who read this book without the advantage of oral teaching.

The two aims which I have kept before me in my work have been—to use language as simple, as transparently clear and unmistakeable in meaning, as possible; and to show always the practical use of the science in its bearing upon daily life and personal health. To be told that I have succeeded in these respects is all the praise I could desire.

F. F. M.

# CONTENTS.


## CHAPTER I.

PAGE

INTRODUCTORY . . . . . . . 1

## CHAPTER II.

RESPIRATION . . . . . . . . 7

## CHAPTER III.

CIRCULATION OF THE BLOOD . . . . . 17

## CHAPTER IV.

"BREATHE FRESH AIR" . . . . . . 30

## CHAPTER V.

DIGESTION . . . . . . . . 47

## CHAPTER VI.

FOOD . . . . . . . . . 60

## CHAPTER VII.

THE HYGIENE OF FOOD . . . . . . 73

## CONTENTS.


CHAPTER VIII. PAGE

Secretion and Excretion—The Liver . . . . 85

CHAPTER IX.

Excretion—The Skin and Kidneys . . . . 98

CHAPTER X.

The Eye and its Health . . . . . . 112

CHAPTER XI.

The Ear—Touch—Taste—Smell . . . . 125

CHAPTER XII.

The Brain and Nerves . . . . . . 137

CHAPTER XIII.

The Work and Health of the Nervous System . 149

CHAPTER XIV.

The Muscles and their Work . . . . . 162

CHAPTER XV.

The Bony Foundation . . . . . . 172

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# THE HOUSE OF LIFE.

## CHAPTER I.

### INTRODUCTORY.

WHO that has ever been ill can question that health is the one thing needful above all others for him upon this earth? One can be both happy and useful without wealth, without rank, without fame; but even the toothache can mar happiness, and one cannot do one's work properly while afflicted with "only a cold." We should expect, therefore, that all people would avoid everything which might take away from them the blessing of health, and would never neglect anything which would preserve it to them.

But when facts are consulted, they have a mournful tale to tell of lives wasted by ignorance and carelessness, and of suffering which need never have been endured. There meets us this startling fact, that there die in this country every year no fewer than *one hundred and twenty thousand* persons who are killed solely by neglect of the laws of health.[1] And we must remember that even this great number is as nothing compared to the still larger one of those who throw away their health without actually losing life itself; who undermine the foundations, and make breaches in the walls, and let decay creep into the chambers of "this breathing house not made with hands," by their neglect of its needs, long before it falls to the earth altogether.

[1] The Report of the Medical Officer of the Privy Council, 1871—the highest possible authority.

This melancholy amount of preventible disease and death is a matter which concerns each one of us, not only individually, and upon far other than merely selfish grounds. For, leaving the personal suffering of a constant invalid out of the question (important though that is), it is the duty of every one towards his neighbour to guard his own health, that he may do his share of the work of the world, carry his due portion of its burdens, and increase the sum of its joys.

It is not meant that one's own health should be the constant subject of one's thoughts. The hypochondriac who weighs his food and measures his walks is generally selfish, and always silly, because his very caution defeats its object. But into absurdity of such a kind no one who works is likely to fall; and as this little book has to show that activity, of both body and mind, is one of the most essential conditions of health, there is no fear that its study will lead to such a mistake.

If it is a duty which we owe to others to endeavour to preserve *our own* health, how infinitely more must it be the duty of those upon whom the responsibility for the health of *others* rests, to acquaint themselves with the laws of life? It is because women stand in this position, because upon them depend the healthful management of the home, and the bringing up of children, that it is so especially necessary that girls should be instructed in this subject.

There is but one useful plan upon which the laws of health can be studied. Many of those laws which are continually neglected are perfectly well known as rules to the people who disobey them. Such are—"Breathe pure air," and "Wash and be clean." The reason why such rules, which everybody knows, are so often disregarded, is that they are rules only. Very few people know why they exist. Their reasons and their importance can only be understood by aid of a knowledge of the

structure of the human body; to put it in large words, which people call "scientific language,"—Human Physiology is the basis of Hygiene.

This is the only way in which health can be effectually studied. If we once understand just what mischief is worked upon our bodies by a certain kind of neglect, there is little fear of our being guilty of it; on the other hand, mere rules, the object of which is not comprehended, stand a very poor chance of being practically minded.

Physiology is a science; the preservation of health is an art founded upon that science. The science is in itself entrancingly interesting, and its study is full of value; but this value is increased, and this interest is heightened, when its application to the prevention of disease is seen. We shall, therefore, here study the structure and the functions of this wonderful house of life, with its numerous apartments, and shall see what each part of the science of physiology can teach of the art of the preservation of health.

Let us begin by taking a brief outline sketch of the arrangement of the house. There is a wonderful combination of chambers and passages, of still-rooms and kitchens, workshops and offices, pulleys, pumps, and pipes; yet the work of each department is done for the whole, the nerves being the messengers, and the blood the porter between one and another apartment.

Every organ does its own distinct work, yet always with reference to the wants of other parts. If we injure one portion of our bodies, in all probability some other will make a mighty effort to do double work. Any organ upon which extra work is thrown receives at once an additional supply of blood. There is sympathy and co-working throughout. Our duty with regard to our bodies is not to alter their already beautiful and perfect arrangements, but to protect them from injury, and to keep them in condi-

tions favourable for their preservation; just as, if we lived in a magnificent palace, with choice woods and marbles and precious stones decorating it everywhere, we should not attempt to alter it or amend it, according to our caprice, but would guard it from the entrance of those who would despoil it, and would watch that even our professing friends and our servants did it no harm.

I have already used a word which I must explain before going on farther—the word *Organ.* All nature is divided into two great classes—*Organic* and *Inorganic.* The first-named class comprises all animals and all vegetables; the second consists of minerals, such as stones and metals, and also takes in water, air, etc. The term *organ* is applied to any distinct part of a body which has some special work of its own to do. Thus, in animals, the heart is the organ of the circulation of the blood, the brain is the organ of the mind, and so on. In vegetables, again, the leaves, the stalks, the flowers, are each and all organs, performing some special office for the life of the whole plant. But in rocks, in a clod of earth, in water, in fire, we do not find anything of the sort; there are no separate parts performing separate functions. The animal and vegetable kingdoms are therefore organised; the mineral kingdom is inorganic.

The bony skeleton forms a sort of foundation upon which the body is built; the muscles and other tissues[1] being padded round the bone in the extremities, and the soft organs in the trunk and head being protected by cases of bone.

The bones forming the head and trunk are so arranged as to make two cavities, or tubes; one consist-

[1] A tissue is, to speak colloquially, the stuff of which a part is made; in other words, it is an elementary structure of the body—a structure which cannot be further divided without quite destroying its construction.

ing of the inside of the head and the inside of the backbone, the other of the inside of the trunk, which is partly enclosed by the ribs and the *pelvis*, or basin, and covered over by the abdominal muscles.

Every one knows that the inside of the head is hollow, and that the brain is contained there; it is not so generally known that there is also a hollow right down the middle of the backbone, and that the substance of the brain is continued in that canal, right down the spine. Such, however, is the fact. And the inside of the brain-case and the inside of the spine together form the first of the two cavities, or tubes, into which the head and trunk of any animal that possesses a backbone (that is, every *vertebrated* animal) are divided.

The second cavity consists of the whole of the trunk, right round from the backbone. This space is closely packed with the delicate vital organs. It is divided into two parts by a large muscle, fibrous in the middle, called the *diaphragm*, which forms an arch across the centre of the body, quite separating the organs which are above it from those which are below it. The use of this muscle is to assist in the act of breathing. The space above the diaphragm is called the *thorax*, or chest; that below it, the *abdomen*, or belly.

Both the shape and the arrangement of the organs of the trunk are very similar in human beings and the lower animals. Those who can, therefore, should open and inspect a rabbit, or some other of our poor relations; and should remember for the future that these creatures, whose structure is so like our own, are like us also in their bodily sensations and needs, so that he who starves or otherwise ill treats a beast is as criminal as though he had done likewise to one of his own species.

The heart and lungs will be found in the thorax; and the diaphragm is pierced by the passing through it of large blood-pipes which leave the heart, as well as

by the gullet, through which the food passes from the mouth to the stomach.

In the abdomen are the stomach, with the liver on its right, the spleen on its left, and the pancreas, or sweetbread, behind it. The coil of the intestines fills up most of the remaining space, and hides, from the front, the two kidneys, which are in the loins behind.

This introductory chapter must not conclude without explaining two words which will be repeatedly used in the book. The first one is

## PHYSIOLOGY.

This comes from two Greek words, meaning literally "The Science of Nature." Human physiology treats of man's body and its vital processes. The term *anatomy* is generally used to express an account of the mere *structure* of the system, and the word *physiology* is applied to the explanation of the *functions* of the parts. The latter term may, however, as you can see from its derivation, be made use of without incorrectness in treating of both structure and function—that is to say, of both how the body is made, and the work which its various parts have to do.

The next word which I must explain is

## HYGIENE.

This is derived from the name of the goddess of health worshipped by the ancient Romans—Hygeia. The word is used by us to denote "The Laws of Health."

These definitions make it possible for the reader to thoroughly understand the power of the sentence which stands on a preceding page—"Human Physiology is the basis of Hygiene."

# CHAPTER II.

## RESPIRATION.

THERE is no more important hygienic precept than "Breathe pure air." At the same time, there is no one which will more fully illustrate the truth that the only way to secure obedience to the laws of health is to explain the physiological principles upon which those laws are based. The reason why we should breathe pure air, and the importance to our health of our doing so, must be found by studying two of the vital processes—*Respiration* (that is, *breathing*), and the *Circulation of the Blood.*

The organs concerned in these two processes are the only ones in the *thorax*, or chest, and above the diaphragm. The lungs are the organs of respiration; the heart is that of the circulation.

The heart lies in the centre of the chest, with its point directed toward the left, and one of the lungs is on either side of it (Fig. 1).

*The lungs* (in the lower animals termed the *lights*) are two grayish-pink bodies, which extend from the collar-bone to just below the bottom of the shoulder-blade. The right lung is a little heavier than the left. The right also differs from the left lung by being divided into *three* portions, called *lobes*, by deep fissures, which go far down into its substance, while the left lung is divided in a similar manner into *two* lobes only.

Each lung is covered by a very delicate shining smooth membrane (that is, skin), named the *pleura* (Lat. plural,

*pleuræ*). The pleuræ completely cover the lungs, and then turn backwards and line the inside wall of the chest, fastening below on to the diaphragm. Each pleura thus forms a shut bag, with only a little fluid inside, the bag itself,

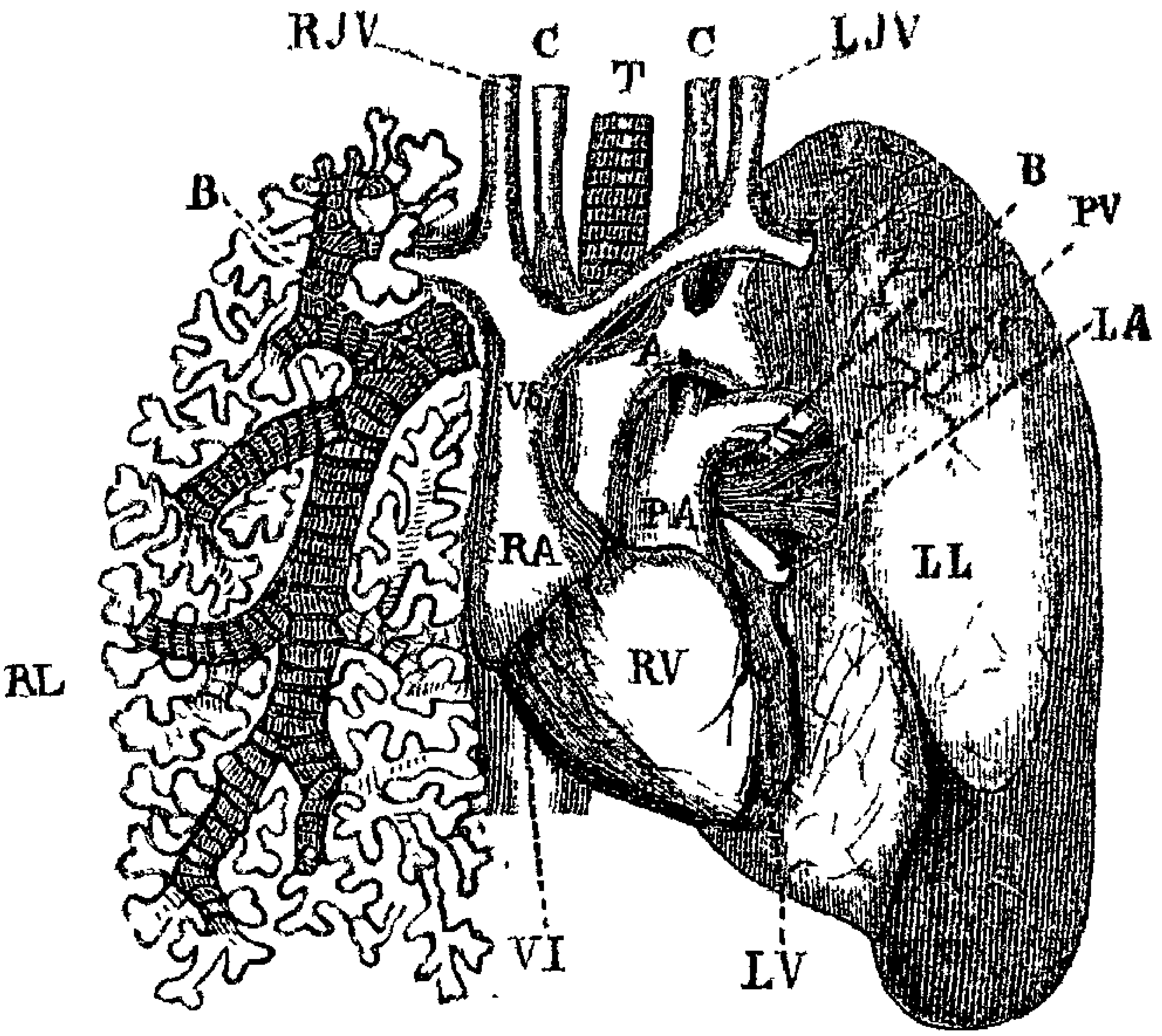


*Fig.* 1.—THE HEART, GREAT VESSELS, AND LUNGS.
FRONT VIEW.

T, trachea, or windpipe; LL, left lung; RL, right lung, dissected out so as to show the divisions of the bronchus; B, the bronchi; RV, the right ventricle; RA, the right auricle; LA, the left auricle; LV, the left ventricle; PA, the pulmonary artery; PV, the pulmonary veins (these veins and artery are shown entering the left lung, but have been removed in dissecting the right lung); VS, the vena cava superior; VI, the vena cava inferior, the two large veins through which the blood enters the right auricle; A, the aorta, the great artery by which the blood leaves the left ventricle; CC, carotid arteries; RJV, LJV, right and left jugular veins. All the great vessels are cut off short, except the pulmonary artery and veins.

but with a lung wrapped up in one half of the outside and the other half of the outside affixed to the chest walls and diaphragm.

There are several instances in the body of fine skins forming shut bags in this manner. The most noteworthy one is the *peritoneum*, which is reflected st upon all the

organs of the abdomen; and there is also such a bag covering the heart, and another one over the brain. They are called *serous membranes;* and they all have between the two layers of the skin a very small quantity of fluid, called *serum.*

The lungs are made up of the following structures:—

*First*, there are *blood-vessels;* that is to say, pipes which have blood in them. *Secondly*, there are *air-tubes*, which I shall immediately describe more fully. These two kinds of pipes are supported and bound together by a substance called *elastic tissue*, the name of which tells something about its powers. Finally, there are nerves and lymphatic vessels. The lung-substance is a combination of all these structures; the air-pipes and the blood-vessels make up most of it.

All the air-tubes in the lungs are made out of one pipe—the windpipe.

If you lean your head back, you can feel a firm tube running right down the centre of your throat; that is the *trachea*, or windpipe. It is a pipe, about five inches long in a grown-up person, opening at the top into the back of the mouth. It is made of a series of rings. These are composed partly of cartilage (that is, gristle), which goes three-quarters of the way round; but right at the back, the last quarter of the rings is a soft yielding substance. The reason for this is that if the rings were made entirely of the soft material, the sides of the pipe might fall together, so that the air could not pass down it, and then we should suffocate; on the other hand, if the hard gristle were at the back of the windpipe, it would obstruct the passage of food into the stomach, since the gullet lies against the windpipe behind.

At its lower end, behind the breast-bone, the windpipe divides so as to form two branches, one of which goes into each lung. These two tubes are called the *bronchi* (Latin singular, *bronchus*); and the place where

each one enters its own lung, which is where the blood-vessels also enter, is named the *root* of the lung. As you will see in Fig. 1, this is nearly in the middle of the organ.

As soon as each bronchus enters the lung, it in its turn divides into two other tubes; then each one of these divides into two (or occasionally three) more, and each of those into two more again, and so on. To put it in other words: each bronchus, having gone into the lung substance, divides and makes two tubes; then those two divide and make four; and the four separate and make eight; and this process of division and subdivision continues, till an immense number of air-tubes are made. These divisions of the bronchi are named the *bronchial tubes*.

Now, whenever one bronchial tube divides to make two others, the two are both *narrower* pipes, and *made of thinner skin* than the one was from which they are formed. Thus each bronchus is narrower, and made of finer skin than the windpipe; and the two first bronchial tubes are narrower than the bronchus by the division of which they are made; and so on. So that, finally, the last pipes produced in the lungs by this continual dividing and subdividing are only about one-fortieth of an inch in diameter, and are made of very delicate skin indeed.

Upon the end of every one of those smallest bronchial tubes there is a little swelling, shaped something like a funnel. The smallest bronchial tube may be compared to the stem of a funnel, and the dilation spreads out from it, as the mouth of a funnel, into which the liquid is poured, does upon its stem. But the dilation at the end of the bronchial tube is not quite smooth, like the top of a funnel; on the contrary, the skin of which it is made bulges out inside into a great number of little pits or depressions, like small caverns in its walls. These tiny recesses are the *air-cells*. Fig. 2 will help you to understand this description.

You would find it very interesting to get the lungs (lights) of some animal from the butcher, and try how far you can trace the divisions of the bronchi.

If you purchased the two lungs still attached to the end of the windpipe, you might, before cutting them at all, blow through a hollow stem of some sort into the windpipe, and you would then see the lungs swell up, and sink down again when you removed your lips from the tube, just as the chest-wall, which covers the lungs, rises and falls when we draw and send out our breath.

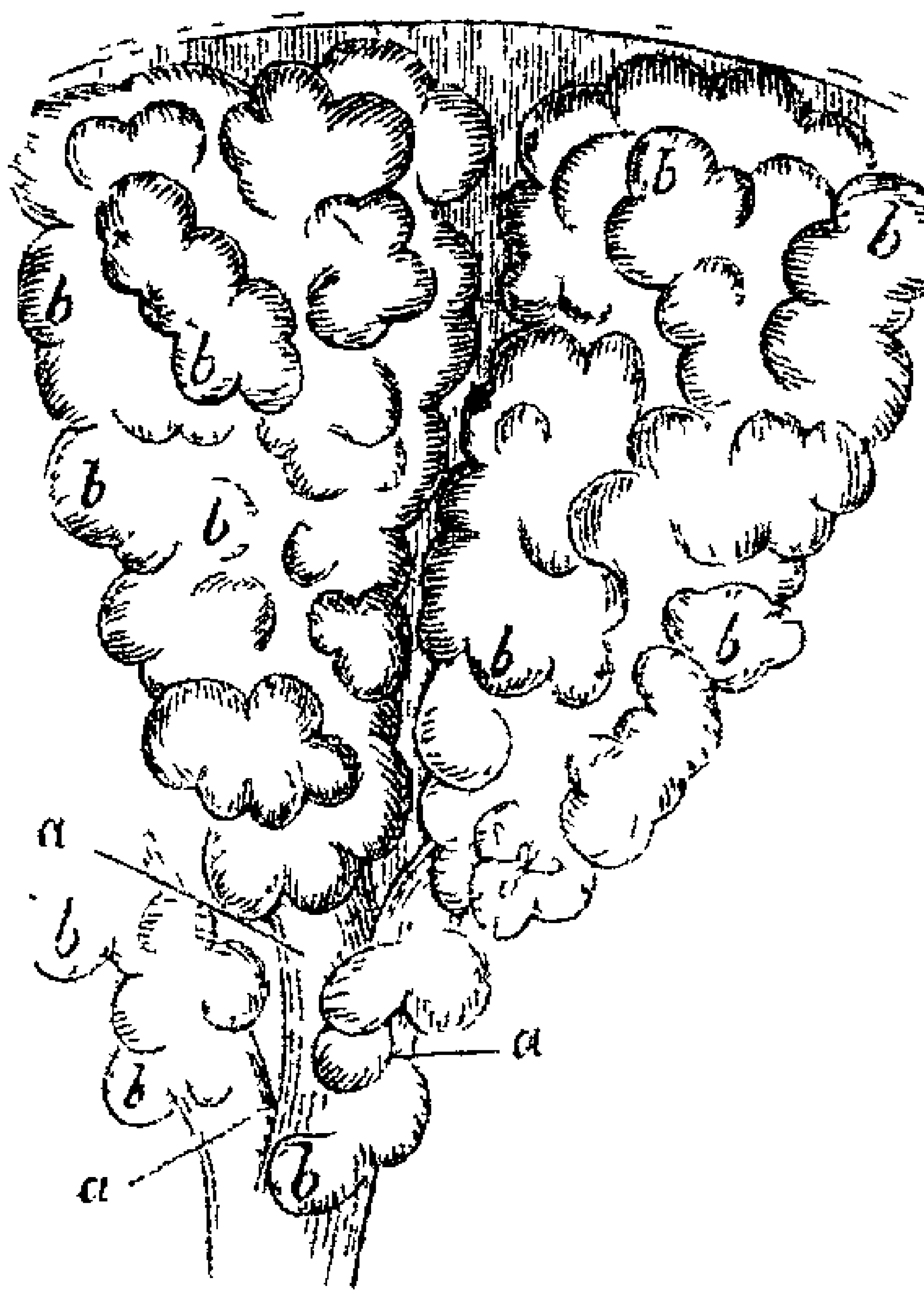


*Fig.* 2.*—AIR-CELLS OF LUNGS MAGNIFIED.

*a, a*, Smallest bronchial tubes, terminating in elongated dilatations (the air-sacs), upon which bulge out *b, b*, the air-cells.

Did you ever wonder what caused that rise and fall of your chest? No doubt you know vaguely that it happens as you breathe; but do you really know what breathing is?

All around us there is an invisible something, which we can feel by waving our hands about in it, and the effects of which are often plainly enough to be seen. We call it, when it is still, the *air*, and when it is in a state of commotion, the *wind*. It is a substance, for it will keep apart the sides of a bladder that is full of it, and it will bear the weight of a kite up towards the sky. It is the same substance that we call *breath*, when it has been down into our lungs; and the act of breathing is simply drawing the air down into the lungs and sending it out

* From Kölliker.

of them again. When the air is drawn in, the bronchial tubes are filled, the lungs expand and the chest rises; when the air passes out the chest sinks down again.

The act of drawing in breath is *Inspiration;* that of sending out breath is *Expiration;* and the whole act of breathing is called *Respiration.*

Why we respire will be seen by and by; I am now going on to explain the mechanism of breathing. The lungs do not breathe simply because they have in them all that multitude of air-pipes. The trachea, the bronchi, the bronchial tubes, and the air-cells, are the series of passages through which the air passes in the lungs; but although the lungs of a dead animal have all these, yet it does not respire. If it drew breath we should know it was not dead.

We make the respiratory effort, by which breath is drawn into and pushed out of the lungs, without, necessarily, our will acting in the matter at all; to put this in more precise terms—respiration is an involuntary action. Many of our most important vital processes are carried on thus, for the very obvious reason that if we had to give our own thoughts to their performance, and *will* them before they took place, we should be able to do nothing else but attend to our own bodily functions. Our brain proper, in which our will and our feeling are seated, does not, therefore, need to take thought of these things for us; still, every organ acts through nerves, and there are special nerves to make the lungs, and the muscles connected with them, carry on their work incessantly.

The action which these respiratory nerves have to order is partly (*a*) that of the diaphragm, that large muscle which separates the chest from the abdomen, and partly (*b*) that of the muscles between the ribs. These are the chief portions of the machinery of breathing. The muscles which form the front of the abdomen also assist in the process.

Wherever in the body we find that elementary structure called *muscular tissue*, it has always one peculiar power of its own. This power, which all muscle possesses, is that of becoming at one time *thicker* and *shorter*; it shrinks together, and gains in thickness just as much as it loses in length.

Now, it has already been said that the lungs are fastened by the pleuræ on to the diaphragm as well as on to the chest-walls. We also know that the lungs are partly composed of *elastic tissue*, a substance which receives its name from its having the same properties as elastic,—that is to say, it will stretch when some force is applied to it, and shrink back to its original size directly the force is removed.

The lungs have elastic tissue in them; the diaphragm is made of muscular tissue. Let us see how they would act, without, for the moment, considering the muscles between the ribs or those of the abdomen.

The centre of the diaphragm is tendinous, and has not the power of contraction; but all round its sides, just where the lungs are fastened on to it, it is made of muscle, and this contracts. The diaphragm, you remember, is shaped like an arch across the centre of the trunk of the body. When the muscular fibres of the sides of this arch all contract, becoming *thicker* and *shorter*, it is clear that the arch must become *flatter*; and in doing this it necessarily drags down the lungs, which are fastened to it, and puts their elastic tissue on the stretch; the air-tubes are thus pulled open, and the air rushes into them to occupy the space so produced. But presently the diaphragm leaves off contracting; then the elastic tissue of the lungs, no longer kept upon the stretch by the pulling down of that muscular arch, does just as a piece of elastic outside the body would do when one left off pulling it—it returns to its original size. But in doing so, it must press upon the air-

cells and bronchial tubes, and squeeze out again from them some of that air which had space to come in when the elastic tissue was pulled down by the diaphragm.

Well, it may be said, this seems to explain the mechanism of breathing; what need is there for the action of the muscles between the ribs, or those covering in the abdomen?

In fact, some persons (the male sex in general) do breathe almost entirely with the diaphragm; but, on the other hand, women usually breathe chiefly by the rib-muscles; and, in all cases, the one method of expanding the lungs fits in with the other, and we breathe partly by the diaphragm, partly by the muscles between the ribs, which are called the *intercostal* (*i.e.* between-rib) muscles.

The ribs are fastened by joints of cartilage on to the spine behind, and on to the breast-bone in front, and the intercostal muscles run between the ribs, from each one to the next. One set of intercostals (called the *external*) run obliquely toward the front, and another set (the *internal*) cross them, running obliquely backwards. By the contraction of the external intercostal muscles, the ribs are a little lifted up, and the breast-bone slightly pushed outwards, at the same moment that the diaphragm is contracting and pulling the lungs downwards. The effect of the movement of the ribs and breast-bone just mentioned is to make the lungs stretch from before backwards, as the diaphragm makes them stretch from above downwards, and the air rushes in to fill this space directly it is made.

The internal intercostals act in precisely the reverse manner, pressing the ribs downwards, and pulling the breast-bone a little inwards. They are, therefore, aids to *expiration.*

The abdominal muscles help to pull down the ribs, and to push up the diaphragm by squeezing on the

stomach and other organs, and pressing them against the contracted arch. They, therefore, help *expiration*, and they come into play chiefly when we cough, or sneeze, or sigh, violently expelling air from our lungs.

Over and over again, as long as we live, these various parts of the respiratory mechanism perform their several actions. The diaphragm contracts and pulls the lungs downwards, and at the same moment the external intercostal muscles raise the ribs, and stretch the lungs crossways; thus the air-vessels in the lungs are opened to their widest extent, and the air rushes into them. Then the action of the muscles just named ceases; the elasticity of the lung tissue comes into play, the internal intercostal muscles contract and carry the ribs down again, and the diaphragm (aided by the pushing against its under side of the abdominal organs, by the muscles which cover them) returns to its arched-up shape; thus the bronchial tubes are pressed upon, and the air, which was immediately before drawn in, is expelled again. Then there is an instant's pause; and then the whole proceeding begins again. This is respiration; and in an adult the whole of these actions are repeated from *fifteen* to *eighteen* times in every minute.

But do not understand me to say that the bronchial tubes and air-cells are emptied with every expiration. We never can, even if we breathe out as hard as possible, make the back and the front of the chest come nearly against each other; there is always a considerable space remaining. The consequence is that the air-tubes always have some air in them, even after the most forcible expiratory effort of which the muscles are capable.

On the other hand, when we draw a deep breath we get more air into our lungs than enters by an ordinary inspiration.

There is, then, a certain quantity of air which passes in and out of the larger bronchial tubes with every

ordinary calm respiration ; the quantity is about 30 cubic inches, and it is called the *Tidal air.*

By breathing out as strongly as possible, calling into play the abdominal muscles, there can be sent out of the lungs about 100 cubic inches more; this is termed *Reserve air.*

But still, as just explained, there will remain in the lungs a certain quantity which never can be squeezed out; this amounts to about another 100 cubic inches, and is called *Residual* (which means *remaining*) air.

Thus, you see, after an ordinary breath is drawn, the lungs contain, in a full-grown person, about 230 cubic inches of air, and only 30 of these move in and out with each breath—the other 200, the reserve and residual air, are, in ordinary breathing, *stationary* in the tubes and air-cells.

Then, by taking the deepest possible inspiration, we can make room in the bronchial tubes, on top of the ordinary tidal air, for about 100 cubic inches more, which is called *complemental* air. Thus the whole of the air-tubes and cells in the lungs are capable, when quite filled, of containing from 320 to 350 cubic inches of air.

The respiratory muscles are very powerful. Mr. Jonathan Hutchinson calculates that the force which they must exert to lift the ribs and overcome the elasticity of the lung-tissue is, in ordinary inspiration, as great as would be required *for lifting* 170 *pounds weight.*

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# CHAPTER III.

## CIRCULATION OF THE BLOOD.

THE word "circulation" means "going round." The blood in the living body continually goes round and round in a circle, composed of a series of pipes called blood-vessels, and including the heart. Through these a stream of blood unceasingly pours.

The *heart* is the centre of the circulation. It lies about the middle of the chest, with the broad part uppermost, and the point directed towards the left side. The Bible, in telling us how Joab slew his enemy Abner, says, "And he smote him under the fifth rib, that he died." It is just there that the point (or *apex*) of the heart lies.

The heart is made of muscle. It is covered outside by a strong serous membrane, which forms a bag in the same way as the pleuræ do, and which is called the *pericardium*.

When the heart is cut open, it is found to be hollow, and to be divided into four cavities. First, a thick muscular wall makes a complete partition downwards, so as to divide the organ, lengthways, into two halves, *right* and *left* respectively; not a drop of fluid can pass through that thick partition from the one side of the heart to the other. Then *each* half is again divided into *top* and *bottom* parts, by a movable partition of skin, through which fluid can readily pass in *one direction*; namely, from above downwards, but not *vice versa*. Of the four cavities thus made, the two top are smaller than the two bottom ones (see Figs. 3 and 4). The former are called

the *auricles*, the latter the *ventricles*—one of each right and left.

The blood-vessels are tubes which convey the blood over the body, just as water-pipes bring the fluid which we drink to us from the reservoir. They are of three kinds, called respectively *arteries*, *veins*, and *capillaries*.

The largest artery in the body, the *aorta*, marked *A* in Fig. 1, rises out of the left ventricle (see Fig. 4). It passes upwards at first, but before it reaches as high as the collar-bone it arches over, and descends beside the backbone, right down to the loins. There it divides into two branches; and these two, after running a few inches, again divide each into two others, and so on, in just the same manner as we saw the bronchi do in the substance of the lungs. All down the trunk of the aorta, too, there are smaller arteries opening out, and going into the head, the stomach, the liver, and all the upper parts of the body; and these side pipes, also, each in its turn, divides and subdivides.

At length, the tubes becoming narrower with every division, the smallest blood-vessels in the body are produced. They are called *capillaries*, which means "like hairs," because they are so exceedingly tiny. Indeed, they are, in many parts of the body, much finer than the hairs upon our heads, being only about one three-thousandth of an inch in diameter. These tiny vessels form a network, one running into another; and the meshes of the net are often even smaller than the tubes themselves. There are an immense number of these little tubes in every organ, and nearly every tissue of the body.

But after the capillaries have formed a network, there begins the reverse process to that which has already been described in the bronchi and in the arteries. *Two* capillaries *join together*, and make *one* larger vessel; and the tube thus formed is called a *vein*.

The veins continue to join two together to make one

larger trunk—exactly the opposite process from what we observed in the arteries—until at length they end in two large veins, which correspond to the aorta in the arterial

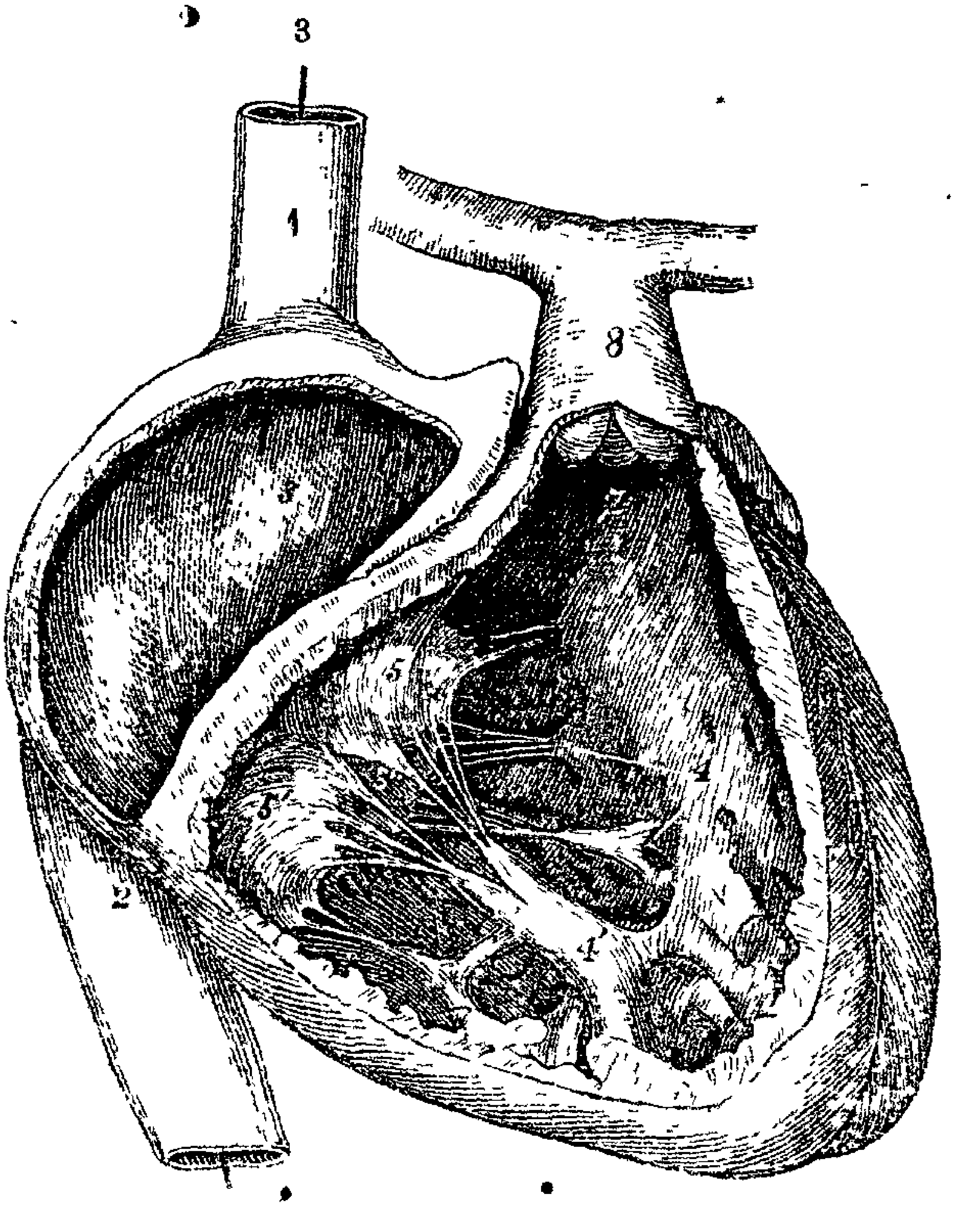


*Fig.* 3.—The Right Side of the Heart laid open.

*a*, The auricle; v, the ventricle; 1, the vena cava superior, cut short, and having a style, 3, 3, passed through it; 2, the vena cava inferior; 4, 4′, papillary muscles; 5, 5′, the tricuspid valve; 8, the pulmonary artery, showing the two branches (cut) into which it divides, one going toward either lung; 7, the semi-lunar valves of the pulmonary artery, represented closed.

system. One of these two veins collects all the blood from the upper part of the body, the other takes all from the lower portion; both of them open into the *right* auricle (see Fig. 3). They are named the *venæ cavæ*; or, separately, the *inferior* and the *superior vena cava.*

We have thus a complete round of pipes, with the

heart as a centre; but remember that the largest *artery* goes out of the *left* side of the heart, while the two largest *veins* return to the *right* side of the heart.

The *arteries* carry blood *away from* the heart; the *veins* bring blood *back to* the heart; and the *capillaries* are tiny thin-walled vessels which form *the communication between the arteries and veins*, like alleys between great streets. When these three kinds of pipes are carefully examined, there are found to be some differences in their structure, as well as in their office.

The walls of the capillaries are composed of a single coat—in other words, the capillaries are made of one skin only; and this is exceedingly thin and delicate. The veins and arteries each have three coats, or layers of tissue; they have a lining membrane, and a mixture of elastic fibrous tissue and muscular tissue next to that, and then what is called connective tissue outside. The chief difference between veins and arteries, in respect of their walls, is that the middle coat is much stronger in the arteries than it is in the veins; so much so that you can tell the difference between the two kinds of vessels in a dead body by the fact that the cut veins fall together, while the arteries are firm enough to keep open of themselves at their cut ends. But the most important distinction between the two is that the veins nearly all have *valves* in them, and the arteries have not. These valves are little pockets of skin, shaped like a half moon, and placed inside the veins with the open mouth of the pocket turned towards the heart. So long as the blood flows onward, as it ought to do, towards the heart, it passes over the back of the valves and holds them flat against the side of the vein; but if the blood attempts to flow backwards, towards the capillaries instead of on to the venæ cavæ, it catches in the open mouths of the half-moon-shaped pockets, and they swell out so as to form a complete obstacle to the reflux of the blood.

The fluid carried by this system of pipes is *the Blood.* We all know what blood looks like to the naked eye. Under the microscope, however, it is found to be very much more complex than it appears at first sight. It is found that the blood is really made up of a clear white fluid, and two different kinds of little bodies which float in the fluid. The little bodies are called the *blood corpuscles;* the fluid in which they float is the *plasma*, or *liquor sanguinis.* Some of the blood corpuscles are red, some white. The red ones give the colour to the blood. They are much smaller than the white ones, but are also about three hundred times as many in number. The red corpuscles have the shape of a piece of money—round and flattened. The white ones are very remarkable for the fact that, in living blood, they continually change their shape; first there is a projection on one side of the corpuscle, and then slowly that draws in and another part projects, and so their outline perpetually alters.

The phenomenon of *coagulation*, or clotting of the blood, shows that the liquor sanguinis really consists of two parts; a stringy substance called *fibrin*, and a thin watery fluid named *serum.* The clot consists of the corpuscles bound together by the strings of fibrin, and the pale yellow liquid which can be seen on top of and around about the clot is the serum. Thus blood consists of liquor sanguinis and corpuscles; but the liquor sanguinis is made up of *two* elements, serum and fibrin; and the corpuscles are of *two* kinds, red and white. It is generally held by physiologists that the white corpuscles are merely red ones in an early stage, and that the red are made out of the white.

The course which the fluid just described takes in passing round the whole system is, you will remember, having the heart as a centre, as follows:—Leaving the *left* ventricle by the aorta, it passes through the arteries,

which gradually become smaller and smaller until they terminate in capillaries, through which the blood goes, and so reaches the veins, and returns through them to the *right* auricle, into which the venæ cavæ open.

Now, the blood which is drawn from an artery, and that which is drawn from a vein, are found to differ considerably. Arterial blood is bright crimson; venous blood is dark purple. Upon closer examination it is found that venous blood has lost between leaving the heart and reaching the veins a large quantity of a gas called oxygen, and has gained about an equivalent proportion of a gas called carbonic acid. Now it is perfectly plain that whatever differences there are between the blood in the arteries and that in the veins must be produced as the fluid passes through the capillaries which join the arteries and the veins. Arterial blood, therefore, is changed into venous blood as it passes through the small vessels which communicate between the arteries and veins. *How* and *why* will be explained hereafter.

Now, there remain to be answered three questions which have very likely suggested themselves to you, and then you can completely understand the circulation of the blood. These are—*First*, What is the force which propels the blood on that long journey through arteries, capillaries, and veins? *Second*, How does the blood get from the *right* side of the heart, to which it returns through the venæ cavæ, into the *left* side, from which it sets out again through the aorta on its course round the system, while we know that there is a complete partition between the two halves of the heart? *Third*, We have seen that arterial blood is changed into venous in passing through the capillaries of the body; but where is that venous blood rechanged into arterial once more? These things are now to be explained.

It is the *heart* which, by its action, supplies the main

force that carries the blood around the body. The heart is really a hollow muscle. The peculiar property of muscle, as you learned in connection with the mechanism of respiration, is that of *contraction*—viz., of becoming shorter and thicker, gaining as much in thickness as it loses in length. The muscular action of the heart is an instance of the fact that many muscles in the body are not under the control of our will. When the muscles in our arms contract, they do so because we order it; but we have no need to command the beating of our hearts. It is clear that it would be impossible for us to maintain by an effort of the will the continued action which is required in these muscles of organic life. Suppose we had to control the beating of our hearts, a muscular movement which never ceases. How weary we should come to be; yet to rest would be to die. How soon we should disorder the regularity of the beats; yet upon their rhythm depend our lives. We could not live at all if muscular action were not sometimes involuntary.

Each involuntary muscle is excited to act, through the agency of the nervous system, by some cause peculiar to itself, which is called its *stimulus*. The stimulus to the heart is its filling with blood. So when the venæ cavæ bringing back the blood pour it into the top part of the right side of the heart—the right auricle—the muscular fibre begins to contract as soon as the blood fills the cavity. All the sides of the auricle become thicker and shorter. In this way, a moment's thought shows, the cavity must become very much smaller; and when the muscular contraction is complete the sides of the auricle are drawn almost close together, and there remains no cavity at all. This is what happens directly the auricle is full of blood; so clearly the blood cannot stay there.

The contracting muscle pushes the fluid out. There are two exits from the auricle, by one of which the blood

must leave it; there are the mouths of the tubes by which it came in, and there is the opening leading to the lower half of the same side of the heart, the ventricle (see Fig. 3). But the mouths of the venæ cavæ are filled up by the mass of the blood waiting to get into the auricle; while the *auriculo-ventricular aperture* (as the opening between the auricle and the ventricle is called) is quite free, and no resistance is there offered. Naturally the blood rushes through the aperture, where it finds no obstacle, and fills the ventricle, only a few drops trickling back into the venæ cavæ. Thus we get the blood into the right ventricle.

Out of the right ventricle there opens a large artery, called the *Pulmonary* (Figs. 1 and 3). This artery divides into two, after the manner of all similar tubes. One of its branches goes into each lung, and in the lung substance they divide and subdivide, side by side with the branches of the windpipe, until they end, like other arteries, in capillaries.

The pulmonary capillaries are exceptionally small, and the meshes of the network which they form are very close. The tiny blood-vessels *surround* the air-cells, and, as it were, cover them with a net. Moreover, generally the capillaries lie *between* two of the funnel-shaped groups of air-cells in which the smallest bronchial tubes terminate, and thus have air-cells on either side of them. By this arrangement, the air and the blood are only kept apart from each other by the two very fine skins of which the vessels and cells are respectively made. Try to understand this, for you will hear the purpose of it presently.

As soon as the right ventricle is filled by the contraction of the auricle, it begins to contract in its turn. Here again there are two ways for the blood to run; there is the opening leading back into the auricle, and there is the mouth of the pulmonary artery. If there

were nothing to prevent it from doing so, it certainly would run back into the empty auricle, for the pulmonary artery already has blood in it.

But then there *is* something to prevent it from running backwards, just as the valves in the veins prevent a similar catastrophe. On both sides of the heart, the auriculo-ventricular aperture is guarded by *valves*, which prevent the regurgitation of blood from the ventricle into the auricle, while they offer no obstacle at all to the passage of blood downwards from the auricle into the ventricle.

This arrangement must be studied a little more in detail. The heart is lined, as well as covered externally, by a tough skin. The lining membrane is called the *endocardium*. At both auriculo-ventricular apertures, this membrane forms three-cornered flaps, just large enough to cover and close the opening between auricles and ventricles. The arrangement is the same on both sides of the heart, with the difference in detail that on the right side there are three flaps, and on the left there are but two. The three make the *tricuspid valve*, the two form the *mitral valve*.

When the blood runs into the ventricles, it gets behind the flaps, and raises them up, until their points meet in the middle of the hole and close it completely. Fine cords of tendinous fibre run from the sides and tips of the flaps to the walls of the ventricles, and prevent the points of the valves being pushed by the blood right through into the auricle, holding them just in the right position, so that they completely fill up the aperture.

These tendinous cords are exactly long enough to keep the sides and points of the flaps touching each other when the ventricles are fully distended, with their walls as far apart as they can possibly be. When the heart contracts, and the sides draw nearer and nearer together till there is no cavity left, the space over which the cords extend (that is, from the wall of the ventricle

to the sides of the flaps) is, of course, much diminished. Thus it seems that they, remaining still the same length, must lose their usefulness; their tension must slacken, and so permit the blood to squeeze the points of the valves up into the auricle, at the very moment when it is most important that this should not happen. It would probably be quite an enigma to most of us if we were asked by what means this disaster could be prevented.

It is prevented in the following wonderfully beautiful manner. The ends of the cords are not affixed to the side of the heart itself, but to certain little projections of muscle, fastened at their base to the wall of the ventricle and standing out into its cavity; these have the tendinous cords attached to their tips. These pillar-like projections are called the *papillary muscles.* When the heart contracts, they do likewise at the same moment; and thereby becoming shorter, they carry down the ends of the cords, precisely as far as is necessary to maintain the tension, and to hold the valves firmly in their place until the ventricle is empty and the contraction ceases. Is not this a beautiful arrangement?

Now let us return to our study of the progress of the blood. We left it at the point when the contraction of the right auricle had pushed the venous blood that the venæ cavæ had poured into it, on into the right ventricle. This blood, prevented by the tricuspid valve from running backwards into the auricle, must, when the ventricle contracts, pass on into the pulmonary artery, through which, as was before explained, it gets into the lung capillaries. The pulmonary artery, therefore, contains dark *venous* blood. It is the only artery in the body which does so; but it is still an artery, because it carries blood *away from* the heart.

The pulmonary capillaries (in the lungs), like those of the whole system, join two together to make a vein, and the veins continue to increase in size and decrease in number

by the same process, until at last *four* great *pulmonary veins* are made, which open into the *left* auricle (Fig. 4). Thus

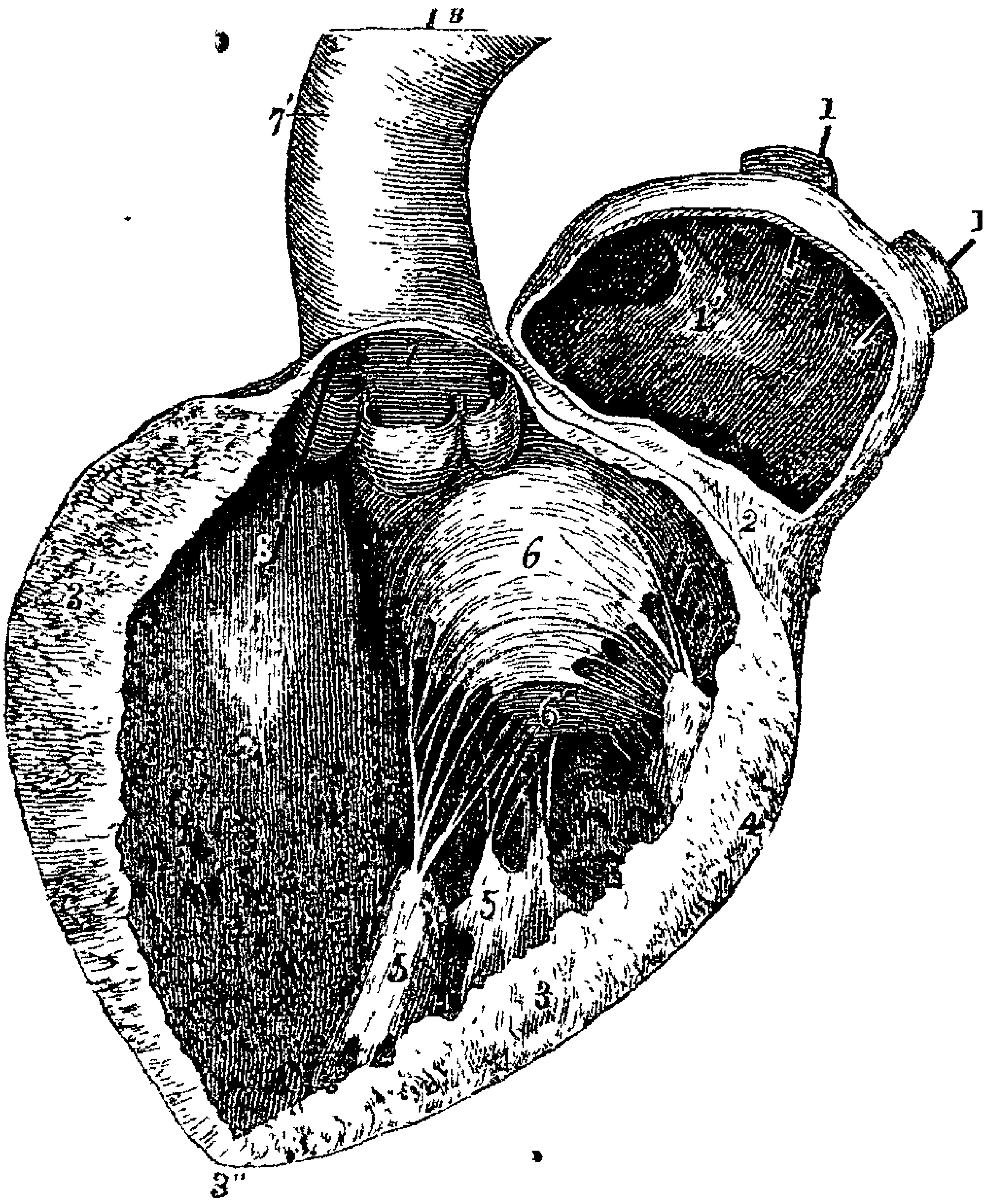


*Fig.* 4.—THE LEFT SIDE OF THE HEART LAID OPEN.

1' In the left auricle; and 8 in the left ventricle; 1, 1, styles (that is, pieces of whalebone) passed through two of the pulmonary veins, showing where they open into the auricle; the veins shown are cut off short, and the other two have been removed with the front wall of the auricle; 2, a small portion of the substance of the heart which has been left around the auriculo-ventricular aperture; 3, 4, wall of the ventricle; 5, 5, papillary muscles, with the cordæ tendinæ attached; 6, 6', mitral valve: 7'. the aorta, cut off just above the heart; 7, placed inside the aorta, which is cut open at its root to show its semi-lunar valves; 8, 8, style passed through the aorta.

you see how the blood gets from the one half of the heart into the other; to get from the right side into the

left, it goes through the lungs; to get from the left side back to the right, it travels all over the body.

Furthermore, just as the pulmonary artery is the only artery holding dark blood, so the pulmonary veins are the only veins which carry *bright arterial blood.* For as the blood was changed from light to dark in passing through the capillaries of the body, so in passing through those of the lungs it regains a brilliant scarlet hue. The cause of and the reason for these changes will form the subject of the next chapter.

Now, you will observe, the three questions put a few pages back are fully answered.

As soon as the left auricle is filled by blood from the pulmonary veins, it contracts and pushes the blood on into the left ventricle. Out of this, as we already know, the aorta opens, and through it the blood starts again on its journey all over the body. About a tea-cupful of blood is sent on in its course with every beat of the heart.

Although the action of the heart takes some time to explain, it is very rapidly performed. The two auricles contract at one and the same moment, and the two ventricles also together the next instant; and the whole of what has just been described occurs, on an average, seventy times in every minute.

The aorta and the pulmonary artery have valves at their mouths, consisting in each case of three pockets of membrane, shaped like the half-moon, and thence called the *semi-lunar* valves, which prevent the blood running back into the heart; but the other arteries have not any, and you can now see the reason why veins should have valves, and why arteries do not need them. It is because (in addition to the presence of much more elastic tissue in the arterial coats than in those of the veins) the force of the heart's contraction has full influence over the arteries, but is much weakened

before it reaches the veins, by being diffused over the capillaries.

Now, let us briefly take a view of the circulation as a whole.

The blood is carried away from the left ventricle by the aorta, and conveyed all over the body by a system of branching and dividing arterial tubes. These tubes finally divide into very small and thin-walled vessels, called capillaries, in passing through which the blood changes its colour, becoming much darkened. The capillaries join one into another to form veins, and the veins, by continuously uniting together, at length make only two large tubes, the venæ cavæ, which open into the right auricle, and pour the blood into that cavity of the heart. The right auricle contracts and sends the blood into the right ventricle, whence it passes into the pulmonary artery, and thus through the capillaries of the lungs, where its colour is re-altered to bright scarlet. The pulmonary veins return it to the left auricle, which contracts and sends it into the left ventricle, from whence it again enters the aorta, to proceed round the body as before.

The circulation through the lungs is termed the *pulmonary*, or the *lesser circulation;* that round the whole body is styled the *systemic*, or the *greater circulation.* The circulation is far more rapid than is usually supposed. The blood streams through the great arteries at about the rate of ten inches in a second, and even in the capillaries, where it is slowest in movement, it goes at about the rate of an inch in a second.

A peculiarity in the arrangement of the blood-vessels supplying some of the abdominal organs will be noticed in connection with the liver.

# CHAPTER IV.

## BREATHE FRESH AIR.

Now, we will go on in this chapter to connect the two preceding ones together, and to see how they show and impress upon us the importance of breathing fresh pure air; of ventilating our dwelling-houses, and preserving open spaces in our towns.

The two facts mentioned in those chapters that must be particularly remembered now are—the way in which capillaries and air-cells are intermingled with each other in the lungs; and how the blood is altered by its passage through the capillaries, both those of the lungs and of the system generally.

The atmospheric air that surrounds us, and which we draw into and send out of our lungs as our breath, is mainly composed of the gases *oxygen* and *nitrogen*, but it has also a dash of a third gas, *carbonic acid.* In perfectly pure fresh air the chemist finds that in every ten thousand parts there are about

7900 parts of Nitrogen Gas,
2100 parts of Oxygen Gas,
3 parts of Carbonic Acid Gas.

This is the chemical composition of the pure air which, in a healthy and properly ventilated place, we draw down into our lungs. But the air which comes out of the lungs has several very important differences from that which went in. When the chemist examines the expired air he finds that, in the short time that it

was in the lungs, it has gained about *four and a half* parts in every one hundred of carbonic acid, and has lost just about as much oxygen; that is to say, expired air contains about

1650 parts of Oxygen Gas,
450 parts of Carbonic Acid Gas,

in ten thousand parts, and only the nitrogen remains practically unaffected by the breathing of the air.

Expired air differs also from pure air (*a*), by being warmer; (*b*) by having more moisture in it; (*c*) by containing a certain quantity of organic (that is, animal) matter.

The most remarkable of these several changes is that in the proportions of the oxygen and carbonic acid. How great the difference between the fresh air that we inspire and the air that we expire is in this respect, a very simple little experiment will show. I hope every one of my readers will perform it according to the following instructions :—

Get a pennyworth of lime-water from the chemist, and let a little of it stand out of doors in a shallow saucer, fully exposed to the air for several hours. Then stir it up, and leave it for about another hour. Upon inspection at the end of that time a thin white film will be seen lying like a veil upon the surface of the clear fluid. Next put some more of the fresh lime-water into a wine-glass, and breathe into it through a straw, or a roll of paper, or other tube. You will see that three or four breaths of expired air will cause the lime-water to become far more turbid and milky-looking than it became by standing for many hours exposed to the pure air which we inspire.

The chemical explanation of this turbidity is that *carbonic acid* comes out of the lungs in the breath, and, mixing with the lime in solution, forms carbonate of lime (*i.e.* chalk), which, depositing in tiny fragments, is seen as a milky hue.

You may make carbonic acid gas, and see that it produces in lime-water the change described, by the simple process of pouring a little dilute hydrochloric acid (which is often called spirits of salts, and of which a small quantity can be bought for a penny or two) upon some pounded chalk, or carbonate of soda, or some of the housemaid's whitening. A great fizzing and bubbling begins directly this is done, and the gas is sent off. It is invisible, but you can readily become certain of its existence. If you take a piece of lighted taper or candle fixed on to the lower end of a wire bent upwards into the shape of the written letter *e*, and lower it into the vessel in which the gas is made, keeping it quite out of reach of the bubbles, you will find that the light goes out, so that you can be sure there is something there other than the ordinary air.

Now, by passing this gas that puts the candle out into lime-water, you learn that it really is carbonic acid gas; because it is distinctive of that gas to make carbonate of lime when mixed with lime-water and to put out a flame. If possible, the acid and chalk should be mixed together in a bottle fitted with a tight cork that has a bent glass tube passed through it, by means of which the gas can be conveyed into lime-water. But if you cannot get this little apparatus, you can make the gas in a mug, and hold that vessel over the glass in which you have your fresh lime-water in such a manner that not a drop of the acid and chalk falls down, but so that something would pass from the mug into the glass if the former were quite full of fluid. In whichever way the gas is passed into the lime-water, you will see that that clear fluid becomes turbid in consequence, just as it did when you breathed into it. That which passes from the lungs, altering the lime-water's tint when breathed into it, is, therefore, carbonic acid gas.

Now, when you remember the fact that the colour of

the blood is changed in the lungs, you may at once guess that there is some connection between that fact and the difference between inspired and expired air. Such is, in truth, the case. The darker blood is, the more carbonic acid gas and the less oxygen it has in it, and *vice versa.* The blood becomes of a lighter shade in the lungs by absorbing oxygen out of the air and giving up to the air-cells in exchange carbonic acid gas.

It has been said how closely in contact with each other in the lung substance are the pulmonary capillaries and the air-cells. Thus, the dark venous blood sent from the right ventricle into those capillaries, and the inspired air drawn in through the windpipe to those cells, are only separated from each other by two fine skins—that is to say, by the membrane of which the cells and blood-vessels are respectively made.

Nevertheless, thin though these skins are, they still are there; and carbonic acid can only get out of the blood, and oxygen can only get in, provided it is a possibility for gases to pass through fine membranes. Now, the question comes, *Can* this take place? Experiment at once replies—Yes, it can. Thin porous membranes present no real obstacle to the admixture of different gases. Thus, if a chemist puts a bladder filled with carbonic acid into a jar full of oxygen, and shuts them up for a given time, the gases will be found to have mixed with one another at last, as completely as they would have done if there had been no bladder between them at all.

In like manner, gases mix with one another, with more or less rapidity, according to circumstances, when there is no skin between them. This is mainly how it is that we can ventilate our rooms; for but for this fact the only way in which we could change the air in our dwellings would be by actually driving out the old and driving in the new, with a fan or a pair of bellows! But different

gases naturally tend to mix so rapidly and readily that we are spared any such necessity.

Thus it is, also, that we get the carbonic acid out of our blood respired into the external air, and get the oxygen out of the fresh air sent down to the blood, notwithstanding that each breath as it is drawn never can penetrate directly down to the air-cells. The residual and reserve air, always stationary in the chest, acts as the carrier between the tidal air and the farthermost air-cells. The carbonic acid mixes with it on the one side and the oxygen on the other, and so by degrees these gases reach their final place—in the case of the oxygen, the blood; in that of the carbonic acid, the windpipe and the outer air.

Now, whenever a certain effect *always* and invariably follows from a certain set of causes, the occurrence is said to be according to a *law of Nature;* and the fact that gases tend, under given conditions (which you may find more fully set out in works on physics), to mix with one another, whether separated by a membrane or not, is expressed as being according to "The Law of the Diffusion of Gases."

When the dark venous blood in the pulmonary capillaries is brought against the air in the air-cells, then, what happens is that, according to the law of the diffusion of gases, the blood gives up carbonic acid gas to the air-cells, and the air-cells give up oxygen to the blood. The immediate result to the blood is a change in tint; it becomes bright scarlet. It passes on forthwith through the pulmonary veins to the left auricle, thence to get into the arterial pipes, and so to go round the body, to be changed once more into dark venous blood in the capillaries of the greater circulation in the way to be presently explained.

The red corpuscles of the blood suck in oxygen gas something as a sponge draws in water; and this makes them lighter in tint, so that the whole mass of the blood, which receives its hue from them, becomes bright in

colour in consequence of the presence of oxygen, and darkens as the oxygen leaves the blood in its progress round the body.

"As the oxygen leaves the blood?" Yes; you could guess that, since the blood becomes darkened again in hue as it proceeds through the systemic capillaries, it must there lose some of its oxygen and gain some more carbonic acid. In fact, every creature "breathing the breath of life" may, without metaphor, be said to be a gaswork, manufacturing carbonic acid gas!

This statement may appear startling; but none the less it is true. The sole aim and purpose of breathing, and the main object of the circulation, is to bring into the body the materials of which that living gaswork makes carbonic acid gas (water being also produced by the same process), and to remove the gas out of the body when it is made.

Of course, we do not make carbonic acid gas as a cotton-factory makes calico, and as a coal-gas company makes that gas—because of the use that the manufactured article will be when ready. We do not make carbonic acid gas for this reason. The reason why we do make it is that *all the heat of our bodies, and therefore our vital force and strength are produced by the process* which *results* in the making of carbonic acid gas and water.

As the water is of the lesser account for our purpose of study, we will set it aside in a few words. Water consists of hydrogen and oxygen; the former enters in the food that we eat, the latter in our breath; and in all parts of the body these two elements join together, forming water by their combination, and producing a certain amount of heat as they combine.

The bulk of the animal heat, however, comes from the combination of carbon and oxygen by which carbonic acid gas is made. This gas is composed of the two elements just named. *Carbon*, like hydrogen, we take

in with our food, as will be farther explained by and by; *oxygen*, we take in, as already shown, by our breathing. The carbon, going round in the blood as digested food, becomes part of the tissues; the oxygen, carried over the body in the red blood corpuscles, acts upon and unites with the carbon and hydrogen in the tissues as the blood runs along the exceedingly thin-walled capillary vessels—gases being able to pass through membranes; and thus carbonic acid and water are produced. In effect, this process is burning up of certain portions of the food and waste particles of the tissues; and just as burning of any substance outside the body produces *heat*, and, if properly applied (as in the steam-engine), *force*, so does the burning of carbon in the body produce heat and force. Thus it comes about that the internal temperature of the body is nearly the same in the hottest and the coldest of climates. Whatever the external temperature may be, the animal heat of a healthy human body keeps at an average of 98½ degrees, simply because the body provides its own fire, and is independent to a great extent of external heat.

The chemical changes which evolve heat are more rapid (that is to say, the fire burns more fiercely), and therefore the blood becomes hotter in some tissues than in others; and, conversely, the blood loses heat in passing through the lungs and the skin; but the quickness of the circulation of the blood keeps the heat equalised all over the system.

I have just said that the mixing of carbon and hydrogen with oxygen, and the consequent production of carbonic acid and water, is, in effect, burning; this is the same thing as if I had said that the essence of burning is the union of these three elements. So it is. A candle, or wood, or any other substance that burns, is chiefly composed of carbon, with some hydrogen, and in burning it draws oxygen to itself, and unites it with the carbon

and hydrogen, producing carbonic acid gas and water. This statement is easily proved by the following experiment:—

Have ready a piece of candle upon the tip of a bent wire, as for the previous experiment (page 32). Then take about another inch of candle, and warm the end of it, so that it will stand upright upon a plate. Light it as it stands there, and turn a tumbler down over it. The larger the glass the more effective the experiment will be. A soda-water tumbler is excellent for the purpose.

Then what do you see? Why, the flame of the candle begins to flicker and grow dim—it burns with difficulty—and presently it goes quite out.

The reason for this is simple. As explained above, the candle burns because the carbon (in the form of grease), of which it is made, mixes with the oxygen of the air, and carbonic acid gas is produced by the union. When the tumbler is turned down over the candle the supply of oxygen is limited; by degrees the whole of that gas in the confined portion of air is used up, and its place is taken by carbonic acid; and then, when there is no more oxygen for the carbon to unite with, the combustion cannot continue, and the light goes out.

To continue the experiment a little farther proves that carbonic acid gas is produced by the burning of the candle. Having your candle upon the bent wire ready lighted, put one hand upon the glass, and turn the whole apparatus upside down. Then, sliding the plate off, dip the lighted candle quickly into the tumbler, and, provided you have been sharp enough, you will see this flame expire instantly.

Now, just as the candle must of necessity cease burning when it can get no more oxygen, so we can no longer live when we are utterly deprived of air. The state of a human being who is placed in circumstances in

which he has no oxygen to breathe is described as *suffocation*, or *asphyxia*; that is death.

Scientific reasoning would show us that this must be so. The union of carbon and oxygen in all parts of the body is the source of animal heat and vital force; carbonic acid gas, which is produced by that union, is waste matter, and the blood needs to get rid of it, at the same time that it needs to take in fresh oxygen. The phrase, "the lamp of life," is thus no unmeaning metaphor. In very truth the lamp must unceasingly burn, and when it expires the body lies inert, motionless, dead. As the candle dies when it has no fresh air, so in the same circumstances, for exactly the same reasons, expires the vital spark in man.

Our combustion produces no flame, because it is much slower than that of the candle, and is damp and smothered. In fact, it may be compared to smouldering rather than to fierce burning, and we have thus heat without flame.

We could have known, then, by scientific reasoning, that if persons were completely deprived of fresh air, by slow degrees the carbonic acid would come out of their lungs to poison the air they had, and the oxygen would be drawn in and used up, and the final end would be death. But, unhappily, we have proofs of the accuracy of such reasoning. In a few sad cases death actually has been caused by deficiency of ventilation.

One of the places in which human beings have suffered and died, by the operation of the same causes as made the candle flicker and expire beneath the glass, is mournfully remembered in English history as "the Black Hole of Calcutta." In the year 1756, 146 English prisoners of war were confined by the tender mercies of one of the native princes of Bengal in a dungeon of only *eighteen feet* square, with two small windows, both in one wall. The 146 poor creatures were forced into that hole, and left,

closely packed, through one hot and sultry night; and there, while the Ameer slept, his victims one by one painfully died of lack of oxygen in their poisoned blood. When the door was opened in the morning there were but twenty-three living persons there. The one terrible night had quenched for ever the lamp of life in 123 men who had been in the full pride of health and strength the day before. More recently (in 1848) the hatches on board the Irish steamer *Londonderry* were battened down tightly during a storm, and when they were lifted seven hours after, ninety of the 150 passengers had fallen victims to the accumulated carbonic acid.

Thus, then, the effect of a *complete* deprivation of a supply of fresh air is death. When the atmosphere has lost half its proper quantity of oxygen, and the carbonic acid is increased so as to form ten in every one hundred parts of the air, life cannot exist in it. An animal placed in such an atmosphere as this will immediately die.

But very much less impurity in air than is fatal to life will destroy health. When there is too much carbonic acid in the atmosphere, as there must be always in an occupied room where ventilation is not attended to, there is not enough of it passed away from the blood; thus the body suffers both from want of oxygen and from carbonic acid poisoning. A high physiological authority says that unhealthy symptoms appear immediately when there is only one-third per cent of carbonic acid in the air breathed. The effects of habitually breathing air even slightly overcharged with the products of respiration are more or less severe, according to the greatness of the evil. Consumption is frequently developed as a consequence of continually living or working in ill-ventilated rooms. General debility and whiteness of the blood are constant attendants upon the unhealthy conditions. Causeless unhappiness, "nervousness," and hysterics, are almost certain results;

and many a woman who endures an infinitude of very real suffering for which she can give no reason, would find herself restored to health if she would but throw up her windows, and breathe in full measure the fresh pure air that will enter. Lassitude and incapacity for exertion come from overcharging the blood with carbonic acid; and many a man who wakes in the morning unrefreshed, and must needs apply to the dram shop for strength to go to his daily task, would instead arouse from sleep full of energy did he but see to the ventilation of the room in which he breathes all night. Those who breathe impure air are also found to be especially liable to all infectious diseases. With respect to the mind, the Rev. Dr. Haughton, one of our most eminent physiologists, says:—"Stupidity in reptiles is associated, as it often is in man, with a venomous and rancorous disposition, and these defects, both intellectual and moral, seem to depend on an imperfect oxidation of the blood corpuscles." And, indeed, we may take it as certain that pure blood and morality are far more closely connected than many good people have suspected.

I have dwelt thus at length upon the addition of carbonic acid made to the air by respiration, and the effects of the accumulation of that gas in our rooms, as being the most notable and important part of the subject. But the atmosphere is further altered by respiration in other ways, which equally show the necessity for constant supplies of fresh air for our lungs.

In addition to having oxygen removed and carbonic acid added, air has the following changes worked in it by being inspired:—

*a.* It gains *moisture.*

*b.* It is *warmed.*

*c.* It becomes charged with decaying ***organic matter.***

The increased proportion of *watery vapour*, made by the union in the tissues of hydrogen and oxygen,

and passed out by the lungs in expiration, is of some importance from our present point of view. When the atmosphere becomes saturated with moisture, the due removal of the excess of water from the blood is, of course, prevented.

The *increased temperature* has very little bearing upon the question of the necessity of free ventilation.

The third alteration above mentioned is, next to the increase in carbonic acid, the most important change. Every living creature passes off constantly from its lungs, and also from its skin, minute particles of waste animal matter, which very rapidly decay. This it is which causes the faint, sickly smell in an empty hall, or any similar place in which a number of people are unhealthily crowded together day after day. Dr. Mapother calculates that a family of only five persons living twelve hours every day in a room send off into it in the course of a year thirty-eight pounds of organic matter. In close, ill-ventilated, dirty rooms this clings to the walls and all the furniture, and, as it decays, does much injury to the health. The free admission of fresh air *oxidises*, and changes the nature of this animal matter. When ventilation is not attended to, and the organic matter decays in a room, the result, according to Baron Liebig, is that effete matters remain in the blood of persons habitually breathing the impure atmosphere in a state which he likened to the soot of an imperfectly-burning furnace. In extreme cases, the result of the collection of great quantities of this animal exhalation, and its being re-breathed, as in the English jails before the days of John Howard, is said to have been to positively originate fever; and there is no doubt whatever that any house where it is allowed to accumulate is in special danger from infectious disease. The decaying organic matter in the ill-ventilated rooms seems to be to the seeds of disease something like what a hot-bed is to the

seeds of plants, making them take root, and grow more quickly and surely.

Now you can see the reason for the precept, "Breathe fresh air;" and it cannot be necessary to add in so many words, "Open your windows often, and provide for a continual current of fresh air in crowded rooms." Is it possible that any person who knows that his own breath becomes his poison, both mentally and bodily, if he respires the same air over and over again, will neglect the simplest means of ventilation, as they are often neglected by the ignorant?

With one or two practical hints I conclude this part of our subject. The first is, that a window should be opened, to ventilate an apartment thoroughly, both at the top and at the bottom. When air is warmed, it rises to the top of the room. If you take a lighted candle to the doorway of a room in which there is a fire, or gas, or many persons, you will find that the flame is blown inwards down by the floor, and outwards up at the top of the doorway, while there is a central point where the flame is quite vertical. Thus, when a window is opened only at the bottom, the fresh air comes in, but the stale heated air does not get out until it has mixed with and contaminated the fresh.

Never let so many persons sleep in a room that there are not at least seven hundred cubic feet of space for each. The cubic contents of a room is found by multiplying together its height, length, and breadth. Servants are often very badly treated in this respect.

To secure a constant supply of fresh air in a small bedroom, while at the same time to avoid a draught upon the sleepers, a very good plan is to replace one of the top glass window-panes by a sheet of fine wire-gauze, such as surrounds a lantern. It can be seen that this effectually prevents draught by holding a candle behind a piece of such wire-gauze, and blowing at it; it will be

found that the flame can scarcely be made to waver by the most energetic puff. The current of air is too finely divided by passing through the minute holes to cause any draught.

When this alteration in the window cannot be made, the same end may be attained almost equally well by the following simple means:—Procure a piece of wood just as long as the window is wide, and three or four inches in depth. Push up the lower sash, and lay this piece of wood along the window-sill, then shut the window down upon it. The result of this arrangement is that, instead of the upper and lower halves of the window meeting each other in the centre, there is a little space left at that place; but the air which enters there is obviously directed up toward the ceiling, and it rises and diffuses itself over the whole apartment, without the least draught being felt by the occupants.

In a good-sized bedroom, where the bed need not be placed directly beneath the window, the top of the window being pulled down an inch or two will secure a good atmosphere for the night.

And let us be assured that a close, foul, unhealthy air to breathe is more dangerous to us than even the dreaded "draughts." How much the knowledge which leads us to this conviction is needed by the people at large, is shown by the obstinate folly with which those persons who live in model cottages, in which scientific methods of ventilation are supplied, often persist in stopping up the ventilators on the plea that they must cause draughts.

The facts given in the preceding chapter about the circulation of the blood, and the knowledge of how the vital fluid conveys whatever it receives to all parts of the system, enable us to perceive the importance of excluding all poisonous gases from the atmosphere. Thanks to that splendid effort of legislation, Mr. Stansfeld's

"Public Health Act," we are to a great extent protected from the poisoning of the pure air of the skies by carelessly conducted manufactures in the course of which hurtful gases are evolved, which were at one time ruthlessly passed out to contaminate the atmosphere. But no Acts of Parliament can keep constant watch upon our private arrangements, nor is it desirable that we should be subject to legislative interference in our homes. Each one of us must keep that house with which he is specially connected in proper condition. Two of the most frequent and dangerous sources of contamination of the air within the precincts of the home, and of consequent poisoning of the blood, and weakening of the vitality, are the house drains and the dust-bin. The former of these should never permit any smell to pass up into the dwelling, and if they become choked, they should be cleared without a day's delay. Sewer gas is believed to be the mode by which typhoid fever poison is introduced into a healthy person's body, and even when this does not happen, breathing that gas is unquestionably lowering to the general health. As regards the dust-bin, it should not be made the receptacle of all the animal and vegetable refuse of the house. As far as possible all such waste should be burned in the fire. If it be put into the dust-bin it slowly decays there, sending off noxious gases for a long space of time.

Marshy neighbourhoods are not healthy. A peculiar gas rises from a marsh, which often causes much sickness among those who respire it.

The lungs are greatly assisted in their work by open-air exercise. The respirations are deeper, and the blood courses more rapidly through the lungs, so that more carbonic acid is passed off in a given time than during repose. For this reason, exercise is a valuable hygienic measure for those persons who have a tendency to that melancholy and fell disease, consumption. In consump-

tion, a part of the lung is unable to perform its proper action; and it is necessary to make that which can work do so as efficiently as possible. Two of the most eminent and valuable of English physicians have made it known that they owe their own lives to regular and systematic exercise. And Dr. Drysdale, physician to the North London Hospital for Consumption, says, in his work on "Climate in Phthisis," that the best advice he can give his patients is to walk as much as possible without fatigue.

I hope some of my readers have thought as they read sufficiently to wonder what becomes of all the carbonic acid which the lungs of animals are continually excreting. If there were no provision in nature for the removal of this, it is clear that, in a comparatively short space of time, the whole atmosphere of the globe would become charged with it, and we should be no better off when we provided for the entry of the outside air into our rooms than we should be without it. At last, the air would be so far composed of carbonic acid, that all animal life would become extinct.

This alarming state of affairs is prevented by the fact that all vegetation performs upon air exactly the reverse of the process which the lungs of animals carry on constantly. We take in oxygen, and transform it into carbonic acid gas; plants take in carbonic acid gas through their pores, and, under the influence of sunlight, remove the carbon from it for their own sustenance, returning the oxygen free again to the atmosphere for us to inspire once more.

Thus it is healthy to have plants in a room, in the daylight. But as it is only under the influence of light that they absorb the gas, it is not desirable to keep them in bedrooms.

I will conclude this part of our subject with a few words about the accidents to which the blood-vessels are

liable. Veins and arteries may alike be cut, and veins which are swollen sometimes burst. The bleeding from a vein is to be checked by tying a tight ligature round the limb, or pressing firmly on the *opposite* side of the cut to that on which the heart is. You see the reason for this: the valves prevent the blood running back from the heart in a vein. An artery, however, bleeds from both ends generally, because one artery leads into another, and there are no valves. If it be possible to find the open mouths, and take hold of them with tweezers, this should be done while the surgeon is sent for. The patient should lie down to lessen the force of the circulation, and cold water, or even ice, if possible, should be applied, because this causes the elastic tissue of the vessel to contract, and so draws the sides together. Is it not much easier to remember what ought to be done, when you know the reason why?

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# CHAPTER V.

## DIGESTION.

THERE is some resemblance between a steam-engine, with its furnace, its chimney, and its ash-box, and a living man. Just as the furnace of the engine must be fed with fuel, which it converts into steam and ashes, so do we need to be supplied with food, and so do the stomach and intestines separate that which our organism can use as force from that which must be cast away as waste. As the steam-engine must have a sufficient quantity of a proper fuel supplied to it before its parts can come into action, so do our bodies require enough of the right description of food to support our existence and the working order of all our organs. We need to learn what are the right kinds and quantities of fuel for ourselves. From want of such knowledge, people are constantly making mistakes, and injuring their own structure. The best way to understand the matter will be to first study the mechanism of the digestive organs; then to learn the properties of the various classes of food-stuffs; and thus to prepare ourselves to have clear ideas on the important subject of diet.

The teeth form the first, in order of their action upon the food, of the organs of digestion. A tooth is made of a substance called ivory, or dentine; and that part which is not protected by being under the gum is covered with a very hard crust of enamel. Inside, a tooth is hollow, the cavity being filled by the nerve, which enters at the

top. Enamel is hard as flint, and is designed to protect the nerve. If it gets chipped, there is every probability that toothache will follow; for enamel never re-forms, and agony begins directly the air reaches the bare nerve. Sometimes the pain may be cured by having the hole in the tooth filled up by a dentist; but if decay has thoroughly taken hold of the suffering tooth, there is no alternative but to have it extracted. When, however, there is no sign of decay in an aching tooth, every other means should be tried before having it taken out; the cause is very probably constitutional, and if it is so, no relief will be obtained by the sacrifice of a useful member. Go, therefore, rather to a doctor than to a dentist with a tooth that aches without showing any sign of decay.

The enamel may be destroyed by acid medicines, or tooth-powders, and by drinking fluids too hot, as well as by an unhealthy state of the saliva, or by violence. The teeth are made to masticate the food, not to crack nuts or bite off ends of cotton. Cleanliness is an important part of the hygiene of the teeth. Tartar pushes the gums away from neglected teeth, and small animalcules fill up their interspaces. They should be regularly cleansed with a tolerably hard brush, aided by the occasional use of a simple tooth-powder. Most of the preparations for the teeth sold in shops contain a large quantity of acid, which is very injurious to the enamel. Common soap, camphorated chalk, and *very* finely powdered charcoal, are among the best things that can be used. Camphorated chalk and charcoal do well mixed together. A few drops of a mixture of equal parts of tincture of myrrh and spirits of camphor poured into the water used for cleaning the teeth is serviceable where the gums are tender.

The teeth are so very necessary to secure good digestion, that these brief hints upon their hygiene are worth my giving, and your attending to.

The second and permanent set of teeth are thirty-two in number, and are of four different kinds. In the front, in each jaw, there are four *incisors*, to cut the food; next, on each side, comes one *canine*, to pierce and tear; then, on each side, two false and three true *molars*, to grind and crush the food. The united action of all these teeth upon the food is to separate it into small particles, while it is turned over and over by the movement of both the jaws and the tongue until it is thoroughly saturated with saliva.

The saliva (or spittle) is a fluid poured out by the six *salivary glands*, three of which are situated on each side of the mouth. The salivary glands resemble in appearance bunches of grapes. The *parotid* pair are the largest; one is just in front of and beneath each ear. Next come the *submaxillary* pair, lower down, underneath the jawbone; and finally, the *sublingual*, which are under the tongue. The fluid called the saliva is secreted (a process of which we have more to say soon) in these six glands, and poured into the mouth through small tubes, or ducts. The saliva is useful to soften the food, and enable the tongue to roll it into a compact ball, ready for swallowing; and has besides an important action upon the starches which are found in food-stuffs, turning them into sugar. If food is swallowed too hastily this important process is interrupted.

The tongue aids in mastication by pushing the food under the teeth, and by rolling it into a mass. We taste by means of small projections of nerve, called *papillæ*, upon the tongue, which you may see start up if you put some vinegar upon your own, and look in a looking-glass. Finally, the tongue passes the prepared morsel of food backward to the gullet.

The back part of the mouth is called the *pharynx*. Here there are several openings. Up above, there are the two back apertures of the nose, and the ends of two

tubes which run between the ears and the throat. Then, down below, there is in front the opening of the wind-pipe, and directly behind that is the mouth of the gullet, or *œsophagus*. And each mouthful that we swallow has to find its way into the right one of all these openings.

The arrangement by which it does so is very beautiful. We may dismiss from the problem the two openings leading to the ear; they are too high up, too small, and too slanting in direction, to be endangered. But there is every possibility of the food entering the wind-pipe and the nose, were there not very complete provisions to prevent its doing so.

There is a gristly lid, called the *epiglottis*, standing up like a sentinel just in front of the *glottis*, the aperture of the windpipe. When this is erect, it, of course, offers no obstacle to breathing. But food cannot get into either the windpipe or the gullet without passing over the epiglottis, and pushing it down so that it forms a complete lid upon the glottis, and prevents the food from falling into the windpipe. The *soft palate*, which you can see if you look down anyone's throat, is the guardian of the apertures of the nose. The food pushes that soft curtain upwards, and it completely covers the entrance to the nasal chambers. By this arrangement, the mass of food has no alternative but to pass in the right direction, over the epiglottis, and into the œsophagus.

The *œsophagus*, or gullet, is a pipe leading from the back of the mouth into the stomach. The principal muscular coat of the œsophagus is composed of fibres placed circularly—round the pipe. It is by the action of these that the food is pushed down into the stomach. As soon as the little ball of masticated food is passed within reach by the tongue, the top fibres of the gullet seize it firmly by contracting around it. The action of muscular tissue is always, you remember, becoming shorter and thicker; so now, the circular fibres

of that portion of the gullet which the food is touching, finding their appropriate stimulus in the presence of the little bolus of food, contract, and become shorter all round the ring. Thus the sides of the ring are drawn together, and the food is pushed down into the grasp of the next circular fibres, which at once contract in like manner. In this way the mouthful of food goes on, step by step, until at last it reaches the stomach. So the food does not fall down into the stomach with a great tumble after it is swallowed out of the mouth, but passes down by degrees.

This shows us another evil likely to result from eating too fast and not chewing food properly, in addition to the one already mentioned that it does not get thoroughly soaked with saliva. Eating too rapidly interferes with the proper passage, piece by piece, of food to the stomach; and a feeling of oppression, like a weight lying upon the chest, may be experienced. Those who have the care of young children just beginning to eat solid food should watch them carefully, to see that they do not bolt their food, as they are very apt to get a habit of doing. There was great philosophy in the address of Joe to Pip (in Dickens's *Great Expectations*), when the poor boy had rapidly hidden his thick slice of bread to give to the escaped convict, but when Joe thought he had swallowed it in so short a space of time: "You'll do yourself a mischief. You can't have chewed it, Pip; you know, old chap, I bolted myself when I was your age—frequent—and as a boy I've been among a many bolters; but I never see your bolting equal yet, Pip, and it's a mercy you aint bolted dead. If you can cough any trifle on it up, Pip, I'd recommend you to do it. Manners is manners, but still your 'elth's your 'elth."

By degrees, then, the food passes though the œsophagus, and enters the *stomach*, the principal organ of digestion. The stomach lies nearly in the centre of the

body, with its widest part toward the heart, from which

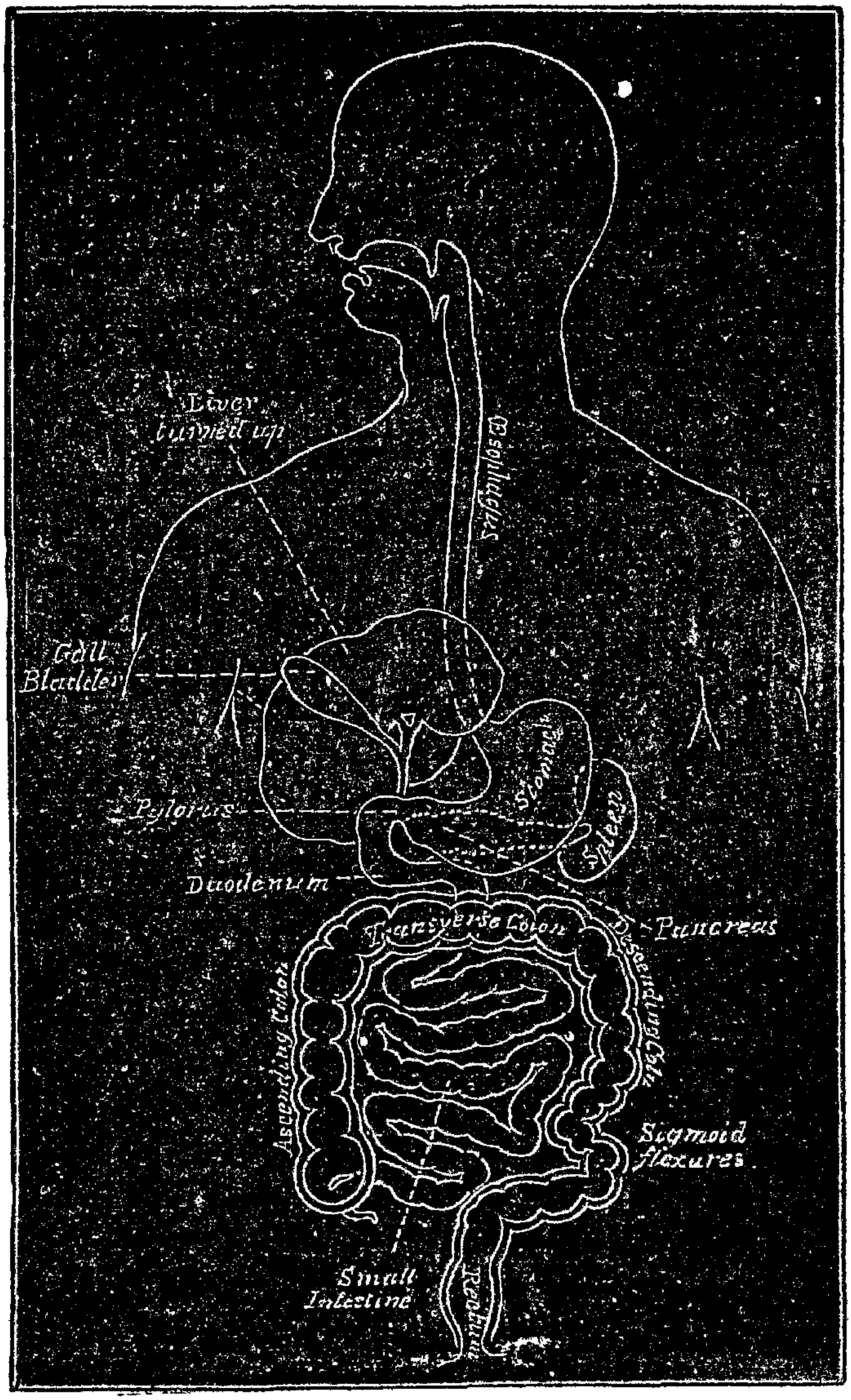


*Fig.* 5.*

it is separated by the diaphragm, the great fleshy muscle

* After Morrant Baker. From Kirkes' *Physiology*, by kind permission.

already described which divides the chest from the abdomen. The gullet pierces the substance of the diaphragm. The shape and some of the relations of the stomach can be seen in the accompanying figures.

It is a muscular organ, lined with mucous membrane, which falls into wrinkles while the stomach is empty but smooths out as the organ becomes distended with food.

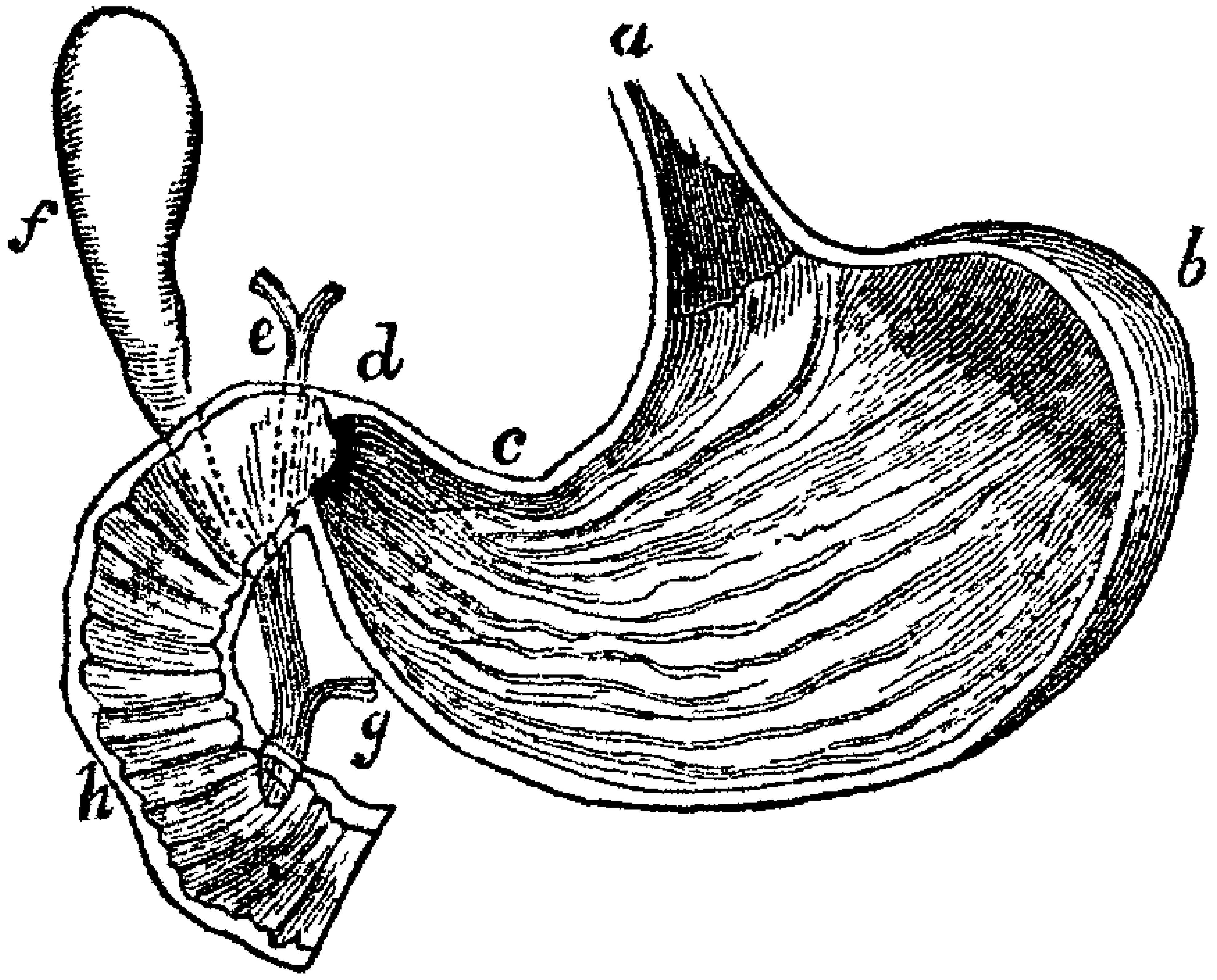


*Fig* 6.—THE STOMACH LAID OPEN.

*a*, The œsophagus or gullet; *b*, the cardiac dilatation; *c*, the lesser curvature; *d*, the pylorus, through which the chyme passes into *h*, the duodenum: *e*, the bile-duct; *f*, the gall-bladder; *g*, the duct of the pancreas (cut), which joins into the "common bile-duct," opening into the duodenum opposite *h*.

When the lining membrane of the stomach is examined with a microscope, it is found to present an appearance like a honeycomb, being everywhere depressed into little pits. At the bottom of each pit can be seen the openings of several exceedingly minute tubes. These are the *gastric glands*, and their office is to secrete (a term which will be explained by and by) and pour out upon the food a peculiar fluid called the *gastric juice*. This fluid is partly composed of *hydrochloric acid*, and partly of a substance called *pepsin*. Indigestion is sometimes caused

by deficiency of pepsin in the gastric juice, and doctors occasionally relieve that disease by prescribing for it a preparation of the pepsin found in the stomachs of other animals. The muscular fibres of the stomach contract when they receive the stimulus of the presence of food, and keep up a sort of churning motion, by which the food is thoroughly mixed with gastric juice, and thus dissolved until it is a soft paste, about the consistence of pea-soup. In this state the digested food is called *chyme*.

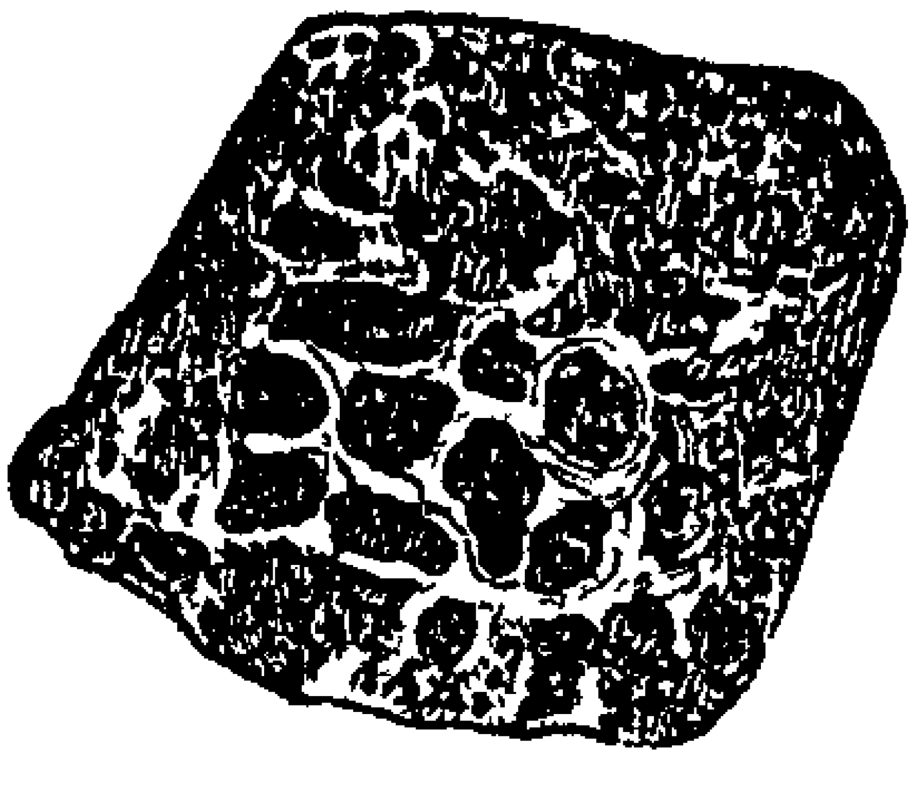

*Fig.* 7.*

Small portion of the surface of the mucous membrane of the stomach, magnified thirty times. The figure shows the minute pits, with the mouths of the numerous little tubes at the bottom of them.

The fact that it is the gastric juice which works this change is proved in two ways. In the first place, when meat or other food is placed in a vessel with gastric juice obtained artificially from the stomach of some animal, and is kept at a temperature about the same as the natural heat of the stomach, the solid mass of food is changed into a thick fluid like chyme; in fact it is digested. Secondly, in cases where, by some accident, an opening has been made in the stomach of a living person, so that the process of digestion could be overlooked, the gastric juice has been seen to pour out upon the entry of food, and the muscular movements of the stomach were plainly directed to thoroughly mixing the fluid with the substance to be dissolved.

The purpose of this dissolving of the food is to enable it to be sucked up into the blood; to use accurate language, to be *absorbed*. For just as gases, as we have already seen, can pass through a moist membrane, so can two fluids, especially when one is thicker than the other, intermingle, notwithstanding that a porous skin

* After Ecker, Kirke.

is between them. You can easily prove this by placing a bladder full of salt and water in a basin of pure water; you will soon find the water in the basin as salt as that in the bladder. This passage of fluids through membranes is called *osmosis.* Any substance which can be completely dissolved in water can pass by osmosis. Thus, the water that we drink, and some portions of the food, are sucked up at once into the veins of the stomach. The rest of the food, not yet sufficiently dissolved to be absorbed, passes on out of the stomach at the opposite end from that at which it entered. It is then, as Fig. 5 shows, in the top part of the intestines.

No particle of food any coarser than it should be is allowed to pass out of the stomach. At the opening of the intestine there is a circular band of muscular fibres called the *pylorus*, or doorkeeper (Fig. 6, *d*). Its office is told by the name that has been given it. Whenever a hard undigested morsel approaches the pyloric orifice, the watchful doorkeeper (the muscular fibres of which find their stimulus in the touch of the solid portion) contracts tightly, and the piece of food has to go back again to be chymified. Such things as fruit-stones, which cannot be digested, do finally overcome the resistance of the pylorus, but they cause pain in doing so. In sensitive stomachs pain sometimes results from the passage of fruit-skins, or particles of raw vegetable, as cucumber, etc.

The top part of the intestine, into which the chyme that passes through the pyloric orifice goes, is called the *duodenum* (Fig. 6, *h*, *i*). Into this part of the bowel there opens a tube, through which the secretions of two other organs pass to act upon the chyme. The first of these new digestive powers is *bile*, the secretion of the liver. The gall-bladder, which is shown in the engraving, rests upon the liver in a groove, and stores up the bile until it is wanted. The second secretion is that of the sweetbread, or *pancreas*, a large gland lying toward

the back of the abdomen. The pancreatic juice and the bile seem to perform much the same kind of actions upon the chyme. They dissolve the fatty matters that have been eaten into very small particles, and so enable them to mix thoroughly with the rest of the digested food ready for absorption by osmosis. Oil, we know, will not mix with water; but if white of egg be added, and the oil globules be thoroughly rubbed down with it, a creamy mixture, called an emulsion, is obtained. A thorough division of the fat particles, and a remixing of the atoms into a kind of emulsion, is what is done by the bile and the pancreatic juice, aided by the movements of the duodenum. The chyme also loses the acidity given it in the stomach, and the starch in it is farther altered. The digested food thus acted upon changes its name a little, and is now called *chyle.*

The intestines are formed by one tube, about twenty-five feet long. To get all this into the small space it has to occupy, it is doubled backward and forward very many times. The small intestine is that part which is nearest the stomach, and is about twenty feet long; it is in this that digestion is completed. The remaining five or six feet of the tube is much greater in diameter, and is hence named the large intestine. The intestine is chiefly composed of muscular fibres, and is lined within by mucous membrane—that peculiar moist skin which forms the inside coat of all cavities in the body; and projecting from the mucous membrane are small processes by means of which the intestine does its work of absorbing into the blood the useful parts of the chyle—all that remains of nutrition in the food that has been eaten.

These little projections are called *villi.* They are set side by side upon the mucous membrane, giving it an appearance like the pile of velvet. In the whole course of the intestine there are estimated to be no fewer than four million villi. Inside each of these minute projections there is a small artery and a vein, with their

capillary network, and also the commencement of a lymphatic vessel.

But we have not yet considered the lymphatic system; now is the time when we must understand it.

All over the body there are to be found other tubes beside the arteries and veins of which we already know. These tubes are called the *lymphatic* or *absorbent* vessels. They begin, in all parts of the body, in nearly every tissue and organ, as fine tubes too small to be seen by the naked eye, which form a network.

The small vessels which come out of this network differ from veins in that they do not continually join together to make tubes greater in size; but they enter, every now and again, small round bodies, called the *lymphatic glands*, in the substance of which the vessels subdivide and form a network, then join into each other, and pass out of the gland on the opposite side as two or more small tubes again. The purpose for which this happens is not known. Finally, nearly all the lymphatics open into the *thoracic duct*, a

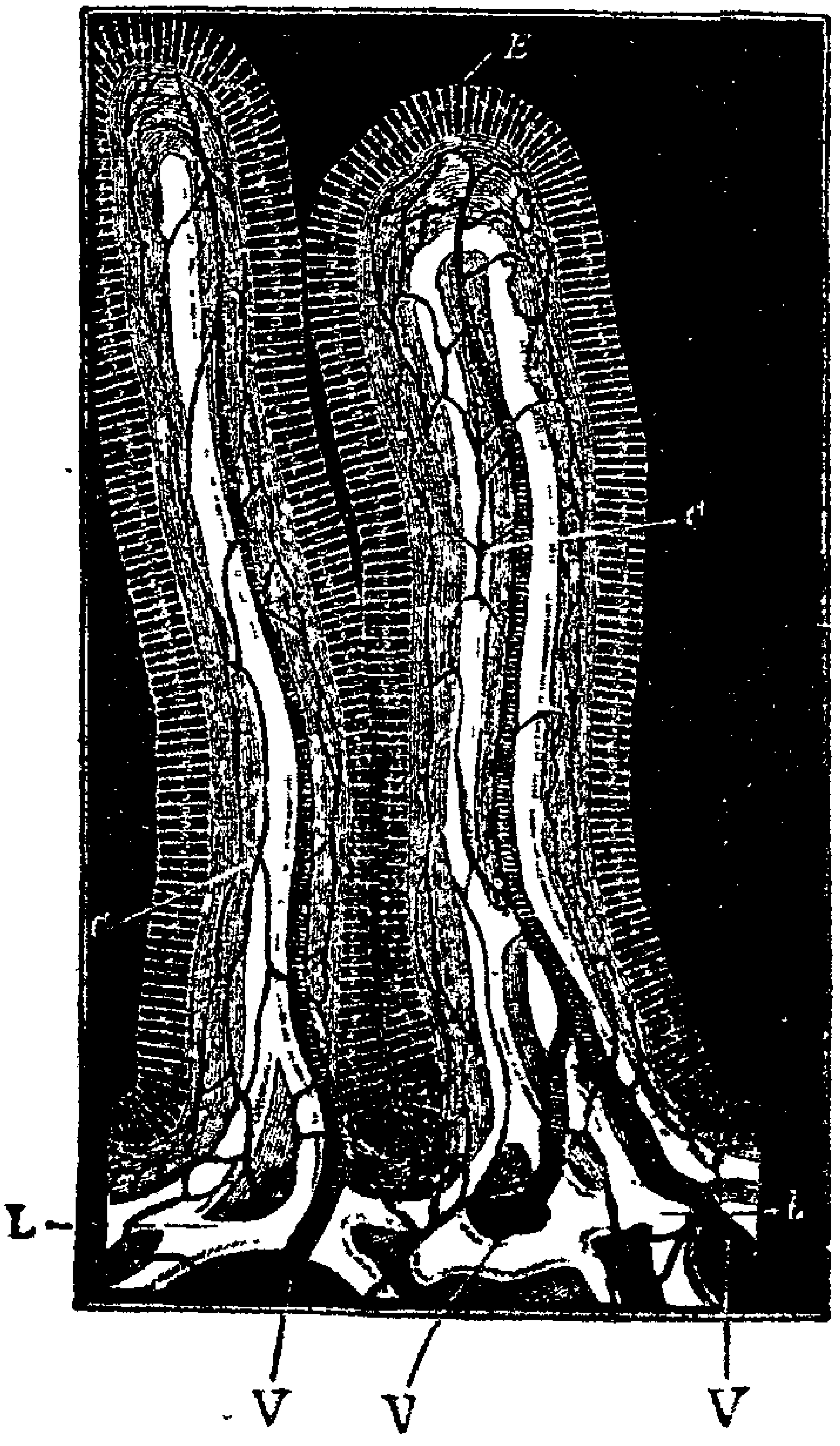


*Fig.* 8.—Villi of Man.*

E, epithelium; C, capillaries; V, veins; L, lacteals.

* From Teichmann, after Kirkes' *Physiology*.

tube about the size of a goose's quill, which runs up from the abdomen to the neck, just in front of the backbone. Through this duct the lymph passes into some large veins in the neck, which are just about to send their contents into the superior vena cava, and so into the right side of the heart. Thus the lymph at last directly enters the circulation, and rushes away with the blood around the whole body.

Let us see what is the clear watery-looking fluid that passes through the thoracic duct from the lymphatic system into the blood.

Partly, it consists of the fluid portion of the blood itself; the blood strained, so to speak, of its red corpuscles. The nutrition of the body is mainly carried on by osmosis. The fluid part of the blood, containing nourishment for the tissues, passes by osmosis out of the thin-walled capillaries. The lymphatic vessels have the power of absorbing through their thin coats, and returning to the course of the circulation, that which remains in the tissues after each one has extracted what it requires for its individual wants.

Partly, as you have doubtless foreseen, the lymph is composed of newly-digested food. I have said that a small lymphatic vessel takes its rise in each villus. In that situation the tubes receive the name of *lacteals* (milk vessels); but they differ in no respect from ordinary lymphatic vessels, except that they are filled with the milky-looking chyle.

Thus we may see the last step in the replenishment of the blood by food accomplished. The saliva commenced the digestion of some portions of the food stuffs, which being further dissolved by the gastric juice in the stomach, certain parts were taken up at once by osmosis into the veins of that organ: the remainder, passing on into the duodenum, becomes there mixed with bile and pancreatic juice, and, now called chyle, is pushed

slowly along the small intestine by successive muscular contractions, similar to those of the œsophagus already described. As it is squeezed along, the blood-vessels of the intestine take up some of the chyle; and the absorbent vessels in the villi draw the remainder of the thick fluid through into themselves, and carry it away, pouring it into lymphatic trunks, and taking it by a longer or shorter route, until at last it reaches the thoracic duct, through which it enters the vein leading to the heart, where it mixes with and replenishes the blood. The whole of the good and nutritious part of the chyle is sucked up into the villi and the veins as it slowly passes through the length of the small intestine. But all food has some husk, woody fibre, or other kind of waste matter about it, of which the blood can make no use. This gradually becomes massed together, as the nutriment is absorbed, and finally leaves the body by the large intestine.

This completes our study of the mechanism of digestion.

# CHAPTER VI.

## FOOD.

If a chemist were to take a human body into his laboratory, and there analyse it, reducing it as far as he possibly could down to its ultimate constituents, he would discover that it was almost entirely composed of the following four chemical "elements"—Oxygen, Hydrogen, Nitrogen, and Carbon. The first three of these are gases, the last a solid, and, difficult as it is to realise, it is nevertheless a fact that these, together with a small quantity of mineral matters, make up the entire body by their various combinations.

If the chemist burned the body, for instance, he would get out of it water, carbonic acid gas, and ammonia gas. Water is a mixture of hydrogen and oxygen; carbonic acid gas is a mixture of carbon and oxygen; and ammonia is a mixture of nitrogen and hydrogen. In addition to these, the chemist would find left behind only a few ashes—about eight pounds, if the body had weighed one hundred and fifty-four pounds. These ashes would consist of various minerals; lime, potash, sulphur, magnesia, and others.

Now, as already has been said, man's body differs in no essential respect from the bodies of all other animals; and the elementary chemical constituents of all those creatures which we use for food are precisely the same as our own—oxygen, hydrogen (these two together making water), nitrogen, and carbon, with various minerals.

But many animals—the sheep and the cow, for instance—never eat anything but vegetables, upon which they grow, develop, and live their lives.

Now, the purposes for which every animal eats are—firstly, to replace the waste of its tissues, which wear away in carrying on their work; and secondly, to provide matter for the production of heat and force in the body.

Obviously, for any food to replace the waste of the tissues, it must be made of the same materials as those tissues. It is clear, therefore, since an animal can live upon vegetables alone, that vegetables also must be made up, as the animal is, of carbon, nitrogen, hydrogen, and oxygen, with various earthy salts. Chemical analysis proves the truth of this reasoning. Vegetables do consist of the same elements as animals, mixed together into different combinations.

And, indeed, every animal does really live upon vegetables; for even animals, such as the tiger, which feed upon flesh alone, are only eating vegetables prepared for them by the unfortunate creatures that they devour. If, by some unimaginable catastrophe, all vegetable life ceased, animal life also would necessarily soon perish from off the globe; for animals can only be nourished upon *organised* compounds (see page 4), while vegetables have the power of turning *inorganic* matter, which they get out of the soil and the air, into their own organised substance, and so rendering it suitable food for man.

Thus there is an eternal circulation of matter, from animal to earth and air, thence into vegetable, and so round into animal again. When an animal dies, its body is resolved, more or less rapidly, into carbonic acid, ammonia, and water, the two first of which compounds are quite useless to another animal, but which some vegetable receives into itself, and transforms into organised compounds of oxygen, hydrogen, carbon,

and nitrogen, so that the particles may again enter into and nourish some living being.

All the many substances that we use as food, therefore, are composed of four elements, together with more or less of earthy salts. Some kinds of food contain more of one of these elements, some more of another; and this fact is made the ground for the classification of food stuffs. All the many nutritious substances which we consume can be arranged under four headings, according to the proportion of nitrogen, carbon, or earthy salts which they contain. These four classes are—first, *nitrogenous compounds*; second, *fats*; third, *amyloids* or *starches*; fourth, *minerals* or *earthy salts*, *water* being included in this class as an inorganic compound.

The first class are the *nitrogenous* food stuffs. This name expresses in itself the peculiarity which separates those kinds of food from other kinds. Nitrogenous food stuffs are those which have nitrogen in them, in addition to carbon, hydrogen, and oxygen. Their principal office, when they circulate in the blood through the body after being digested, is to repair the actual waste of the tissues. Hence we may call this class of food the *flesh-formers*; though it must not be understood from this that they have no share in the production of animal heat, since it is now held by all physiologists that some heat is produced by the using up in the body of nitrogen. At the same time the essential object of nitrogenous food is to form tissue (other than fat), and only these foods do fulfil that end. You must quite understand, also, that in nearly everything that we eat there is more than one class of food. Thus, in an egg, in a potato, in a loaf of bread, or in a joint of meat, you have a combination of two or three of the classes. It is of particular elements in the various articles of food that I am now writing. Thus, among nitrogenous compounds—under this head comes

that substance of which the white of egg is composed, called *albumen*; *gluten*, which is found in flour; *casein*, the chief component part of cheese; the *fibrine* of blood, and such substances as *gelatine*, and *legumin* which is found in beans. But, at the same time, an egg is not all white; flour contains starch as well as gluten; and although cheese is made out of milk, yet it is not the whole of the milk. You will see, however, that before you can know the value of any given article of diet you must be acquainted with the proportion which it contains of each class of food, and the quantity of each which the body requires. The latter is what you are reading about just at present.

The nitrogenous food, you would observe, is found alike in animal and vegetable articles of diet—in eggs, milk, and flesh, as well as in flour, cabbages, and beans. It has been found that these compounds are identical in animals and vegetables. The nitrogenous compounds are often called *proteids*, from a Greek word expressing the primitive state of living matter, because the four elements which the nitrogenous foods contain are found in all living things, whether belonging to the one or the other kingdom. This is probably the best name for them.

The second class of food is the *fats*. This includes oils, butter, animal fat, and the like. The most important difference between the first class and this one is, that fats are composed only of carbon, hydrogen, and oxygen; there is no nitrogen in them at all. Fat is not, therefore, a flesh-former, and it would be quite impossible for a person to live who ate nothing but fatty substances. The office of this class of foods is to sustain our heat. We already know that when carbon combines with oxygen in the body, heat is produced; and as about eighty in every hundred parts of a fatty food are carbon, we see how the heat of our bodies is largely produced by this kind of food.

The third class of food-stuffs are called *amyloids*, or starches. In this class are included all kinds of sugar and gums. These are made up of just the same elements as the fats—that is, of carbon, hydrogen, and oxygen, without any nitrogen; and differ from fats only in the proportion of each material. In the fats, as just mentioned, eighty parts in one hundred are carbon; in the amyloids, only forty parts per hundred are composed of that element. The amyloids are also, of course, body-warmers, and not flesh-formers.

I must here remind you of some facts which were stated in the last chapter. You will remember that I mentioned that the saliva, and, later on, the pancreatic juice, had a peculiar action upon the starch found in bread and other vegetables, turning it into sugar. The reason for this action is that starch cannot be dissolved sufficiently to be absorbed by osmosis, while sugar is very easily so taken into the system. It was said also that a considerable portion of the chyme was sucked into the blood through the delicate coats of the veins of the stomach. I must now add what you would not then have comprehended—that it is the digested proteids, and any portions of sugar which the saliva may have prepared, that are thus taken directly into the circulation. Finally, you will remember that I said that fats passed into the intestine, and were only digested there by their admixture with bile; reaching the current of the blood through the lymphatic system. Most vegetables also are finally digested in the intestines.

The fourth class of food-stuffs is composed of *water* and different kinds of *salts*—all inorganic principles. *Water* forms a very important part of our food. A man weighing one hundred and fifty-four pounds (eleven stone) is calculated to have about ninety pounds of water in his body. Its use is to dissolve the food (because, you know, osmosis is the passage of *fluids* through membrane, and undissolved food cannot be

absorbed) and to form the numerous fluids of the system. *The salts* are every whit as necessary to us as the flesh-formers. We need lime for the formation of our bones, phosphorus for the brain, iron for the blood, magnesium and potash for the tissues, sulphur for the hair, and common salt in very many ways. These various salts are taken by us all without our knowing it, generally speaking. They are, in more or less quantity, in nearly everything that we eat.

I am afraid that you may have been finding this all rather dry; but we are now going on to its practical application, and that will be more interesting to those who have no taste for "pure" science.

You must remember that from our food we obtain all our force, all our working power, whether muscular or mental, we replace our tissues and replenish our exhausted economy. For every effort of any kind that we make, so much force is expended, and so much tissue is used up. Those who work most, therefore, require most food, and the greater the exertion the more plentiful and nutritious the food should be. As the old rhyme had it—

> "Black hands that work must have plenty to eat,"

and so likewise must the white hands that guide the pen of the statesman, the thinker, and the student. Power is in direct relation to the quantity of food (not *eaten* but) healthily absorbed. Dr. Lankester tells a story of a great railway contractor who sometimes had to discharge a hundred men in one day, and who used, upon such occasions, to go round the works at dinner-time, and select the men with the poorest appetites for dismissal!

To eat more food than can be used in the body, or to eat too great quantities of proteids, and not enough of carbonaceous food, or *vice versa*, is, however, a source

of weakness, and not of strength, since the act of digestion itself uses up some of our force. We must, therefore, instruct ourselves upon these points, if we would eat our food to the best advantage.

Physiologists calculate the quantity of nitrogen and carbon used up and excreted daily by an ordinary man, and gather thence that he needs about *four thousand grains* of *carbon* to *three hundred grains* of *nitrogen;* that is, about thirteen times as much of the body-warmer as of the flesh-former.

Experiments upon animals have shown that it is possible to live healthily for a long time upon proteids and water, because the former contain carbon as well as nitrogen. But animals fed only upon fats or amyloids very quickly begin to lose weight, and soon die, because these classes of food contain no nitrogen, no flesh-forming material. We *might*, therefore, live upon such substances as white of egg, etc. But this would be a most extravagant way of living, because, to get the proper quantity of carbon out of such foods, we should have to eat very much more nitrogen than we required.

For instance, in white of egg, which is nearly pure albumen, there are about three and a half times as many parts of carbon as there are of nitrogen. But, as was just said, a man requires in his daily food thirteen times as much carbon as he does nitrogen. Before he could obtain from white of egg, therefore, as much carbon as he needs, he would have to eat four times the necessary quantity of nitrogen. Thus, he would have a large surplus of nitrogen in his body, which would be wasted, and have to be carried away unused by the appointed organs; and both these and the digestive apparatus would be dreadfully overworked.

But as nearly all the things that we eat are composed of two or more of the classes I have named, we do not get deeply into this sort of difficulty practically, notwithstanding that there is much waste from ignorance of

what this chapter teaches. But experience has usually taught man what are the best kinds of food for given circumstances, and in some degree, how he should combine his various articles of diet to get as much good out of as little substance as possible. Thus, the natives of Greenland eat large quantities of that fat called blubber; while the people of tropical regions, in their hot seasons, subsist almost entirely upon fruits, in which there is scarcely any carbon. Men in different parts of the globe eat very strange things, as it appears to us; but life would not exist in any place where it was not possible for living creatures to obtain just those foods which are suitable to the climate and circumstances.

A few words about peculiar foods will give our thinking faculties a comfortable rest.

Dr. Livingstone remarks, in one of his works, that his children, travelling with him in Africa, thought a dish of a kind of caterpillar stewed a great delicacy. Mr. Bates, author of *The Naturalist on the Amazon*, said that the flesh of the spider monkey was the best meat he ever tasted. Elephants' hearts and feet are said by Mr. Baldwin, in *African Hunting*, to be very tender and good. The Africans eat also the flesh of alligators. The Chinese, as well as that often-mentioned delicacy, "puppy-pie," eat a kind of sea snail, stewed; and seem to be partial to various kinds of raw fish. The Russians also eat raw a species of salmon; and the Hottentots eat ants uncooked. But we in England must not profess horrors at such an idea as this last; for our most esteemed cheese is that which produces the most mites, and game and venison are purposely kept by our cooks until they are "high." It is fortunate for the gourmands who eat this sort of food that the gastric juice has great deodorising power.

We have now studied the special action in the body of each of the four classes of food-stuffs; and we have

learnt that the proper proportion to be kept between the nitrogenous and the carbonaceous matters in our daily diet is three hundred grains of the former, to something more than four thousand of the latter. To enable every one of us to construct his own table of diet, it is only now necessary to learn in what proportion the elementary constituents are present in some of the most common articles of daily food.

Meat, like all other so-called "solid food," contains a large proportion of water—no less than seventy-two parts per cent; that is to say, seventy-two ounces in every hundred ounces of meat are water. About fifteen per cent is the flesh-former, albumen; and about eight per cent would be fat. Cooking the meat makes a good deal of difference. Water is driven out of the meat, if it be roasted; or drawn out if it be boiled. This is the reason why meat always loses weight in cooking. A pound of raw meat, therefore, will be less, so far as weight goes, when it comes from the cook. If properly treated, it will not have lost much of its nourishing power; but since it has got rid of a good deal of water without parting with its nitrogenous and fatty matters, it is clear that more parts in a hundred must be actual food. Cooked meat, then, is composed of about fifty-four parts in one hundred of water, twenty-seven of albumen, and, if the gravy be used, fifteen of fat. One pound of uncooked mutton or beef contains about 184 grains* of nitrogenous, and 1854 grains of carbonaceous matter.

Few vegetables contain so much nutriment in so small a bulk as does meat; it is found also to be more quickly and easily digested than vegetables. Meat contains a peculiar principle, called kreatin by chemists, which acts as a stimulant to the system, and the potash salts

* There are 437½ grains in one ounce avoirdupois. The nutritive values here given are taken from Dr. Letheby's analysis, in his admirable work on Food.

which are found in meat assist the assimilation of food. Consequently, a meal that includes meat seems much more refreshing and satisfying than one without it. The presence of these extractives makes extract of meat valuable in weakness and exhaustion. These are facts which it is necessary to know before any one can form an opinion upon vegetarianism, the advocates of which would persuade us to leave off eating meat of every kind. There are points of resemblance in the teeth of man to those both of animals that subsist entirely on herbs, and of animals that eat flesh; this seems to show that a mixed diet is the proper one for man, and the length of the intestines goes to prove the same thing. At the same time, it is beyond question that health and strength may be maintained on a well-selected diet of vegetables alone; and those who subsist, like John the Baptist, upon the fruits of the earth, are ensured against the danger of eating parasitic disease in meat.

The *measle-worm* (Fig. 9), which exists in the flesh of diseased pigs, produces *tape-worm* in the human subject, when the eggs are eaten. The flesh of a suspected pig should always be thoroughly cooked, since these eggs are destroyed by a heat of 160 degrees.

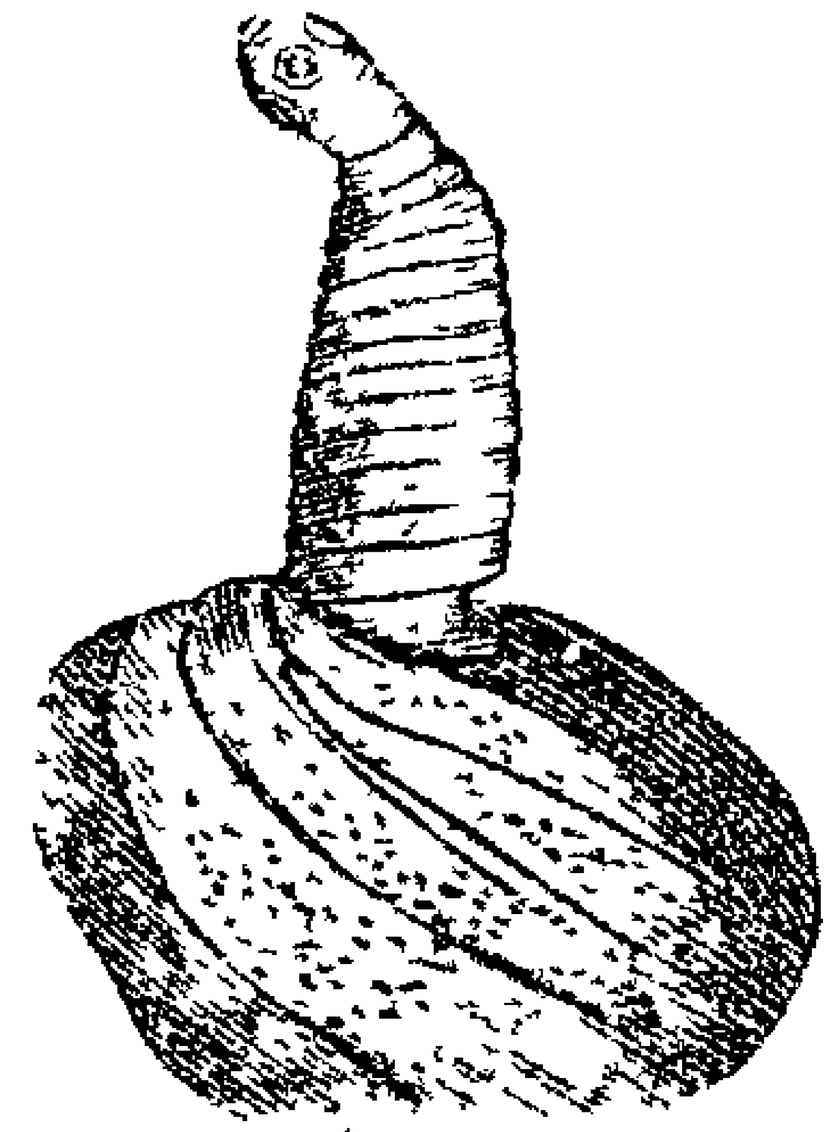

*Fig.* 9.—MEASLE-WORM

A diet of meat alone would not be a physiologically economical one; more nitrogen than necessary would be taken before the proper quantity of carbon would be obtained. When bread or potatoes are also eaten, the proportions are better kept.

If we seek to obtain our nitrogen from the vegetable world, one of the best articles of diet is oatmeal. This valuable grain contains 2831 grains of carbon and 136 grains of nitrogen in every pound. The only

vegetable food which really contains more nutriment in one pound than does meat, is split peas. These have 2699 grains of carbon and 248 grains of nitrogen in every pound. Look back a page, and see how much this exceeds meat.

But most vegetables are composed chiefly of water and starch. Parsnips, turnips, and marrows are the least nutritious of all, containing only about 12 grains of nitrogen and 300 to 500 of carbon in the pound. Potatoes have 769 grains of carbon, and 22 only of nitrogen; so that to obtain from them the necessary 300 grains of flesh-forming material, a man would have to eat at least 12 pounds of potatoes, and in those there would be, of course, very much more water than would be good for him, and excess of carbon. The Irish poor, who very nearly live on potatoes, supply their deficiencies by drinking milk, or at least butter-milk, both of which, as we shall see presently, contain much nitrogen. Green vegetables have 420 grains of heat-forming, and 14 grains of flesh-forming material.

The great value of fresh vegetables, however, to people who eat meat, is not so much the small proportion of carbon and nitrogen which most of them possess, as the salts which they give, and which we cannot obtain so healthily in any other form. People who are deprived of vegetables and fruits, as are sailors on long voyages, get that distressing complaint, scurvy. In most fruits there is scarcely any nutritive matter; but there is a good deal of potash in them, especially in lemons and limes. Not the least service that the great navigator, Captain Cook, did the world, was that of demonstrating the possibility of keeping a ship's crew healthy during very long voyages by means of attention to this point, and now every vessel that sails under the English flag must be provided with lime juice for preserving the health

of the poor sailors, to whom fresh vegetables are impossible luxuries.

Bread, "the staff of life" in this country, demands a little special attention. In a pound of ordinary baker's bread there are 1975 grains of carbon, and 88 of nitrogen. Thus, about four pounds of bread would give the required quantity for a day's food of both heat and flesh forming material; but more than enough starch would thus be taken, although the good *balancing* of these two elements of food in bread is one of its great recommendations. Bread is deficient in fat; hence, butter is eaten with it.

But the small proportion of fat which wheat does contain, together with other valuable matter, is wasted almost always in England. Directly beneath the thin skin which covers a kernel of wheat is a dark-brown layer, which contains both a good deal of gluten (the nitrogenous part of the grain), and most of the oil of the wheat. This dark portion of the kernel is precisely that which the miller bolts away from the flour, and calls bran. Many of the mineral ingredients of wheat are also thus thrown away. The whiter flour is, the more carefully has the dark outer layer of the wheat been removed; and in the very finest flour there is only found 1 per cent of mineral food-stuffs, while in "brown" flour, as that is called which is made of the whole kernel of wheat, there are about six parts per cent salts. In addition to the greater quantity of nutriment contained in brown bread, it is found that its use prevents constipation; and there is scarcely a more injurious habit than that of constantly taking quack pills. For more than one reason, therefore, the occasional substitution of brown for white bread in the daily diet is to be recommended.

Milk must be mentioned here as an article of food; it cannot fairly be classed among the beverages, with which our next chapter will deal. In new milk there

are 599 grains of carbon per pound (*i.e.*, three-quarters of a pint), and 44 of nitrogen; twice as much of the latter as in potatoes. Cream is fat; hence skimmed milk has less carbon, but the same nitrogen. Butter-milk has 387 grains of carbon, and 44 of nitrogen. When milk enters the stomach, it is turned into curds and whey by the gastric juice; the water is at once sucked up by the veins of the stomach, and the curds are regularly digested. Milk contains too much water (86 per cent) to be used alone as a food; but in combination with bread, potatoes, or, above all, with oatmeal, it is one of the most valuable and easily digested articles of diet. It is nature's typical food, upon which the young of most animals live for a considerable time; as we have seen, it contains exactly the proper proportions of nitrogen and carbon, and the salts are also found in it in precisely the right quantities.

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# CHAPTER VII.

## THE HYGIENE OF FOOD.

MY readers are already aware that liquids are as much a portion of our diet as solids. The only necessary fluid food is pure water; but we take various beverages in our daily diet which are of the greatest hygienic importance. The influence of these fluids upon health is to occupy us now for a little while.

The one essential and natural beverage is pure water. Beautiful in its clear sparkle as the diamond for which men's lives have been spent, sweet and refreshing as the nectar which the ancients imagined for their gods, water would be the most highly-prized of beverages but for the fact that it is as easily obtained as it is really valuable. Unfortunately, many persons are only able to judge of the value of a thing by the difficulty which they have in becoming possessed of it. Thus the very reasons for which men should perceive the suitability of water, in its pure unadulterated condition, for their ordinary drink—the facts that it is everywhere, lighting up every landscape; that it is prepared in Nature's own distillery, and that every lake, every river, every mountain stream from which we drink is fed directly from the skies; that the lower animals, whose strength is often so much greater, and whose lives are often so much longer than man's, have it alone for their thirst—these very facts are foolishly misinterpreted to mean that artificial drinks are more worthy of that lordship over Nature

upon which the vanity of man so prides itself. It verily seems as though some people do ignorantly believe even science itself to teach that a man should never quench his thirst with water except when he can get nothing else. I have been seriously asked, more than once, if I did not hold the drinking of pure water at meal times to be a fatal practice?

Dismiss from your minds any such grievous and hurtful prejudices against the freest use of this necessary food in its pure state. It is true, every variety of artificial beverage is really only water in a sophisticated condition; but it is most necessary for health to take, in the words of Dr. Lankester, "a portion of the water we consume as pure as it can be had." It is the water itself that is the necessary of life. By adding to water you may injure your health, but it is impossible that you can improve the pure liquid for the ends for which your system needs it. Water, and water alone, can dilute the food and supply the body with its fluids. Substances added to the water may interfere with, but cannot assist, its work.

All our supplies of fresh water come from the vapour gathered in the air. But it makes a good deal of difference whether we take it as rain-water, direct from the air, or whether it passes through the ground, and reappears as a spring or a well before we drink it. Rain-water is not often drunk in this country; but in Venice, and other cities where it is used, it is found to be healthy. Water, as before mentioned, is one of the principal sources by which we take in our necessary salts. These are, of course, dissolved in the water; and their quantity is found by adding chemicals which will make the mineral matters separate from the fluid, and by evaporating it and weighing the residue. Rain-water contains about two grains of solids to the gallon.

Water becomes changed by the character of the soil

through which it runs, and it is in this way that mineral springs are produced. Too great a quantity of any salt in it will render it injurious to health. The best water is that with which soap rubs well, and in which vegetables cook readily. Water which has an unpleasant smell is not fit for drinking.

The impurity in water which is most commonly dangerous to health is decayed organic matter. Shallow wells and springs, especially in the neighbourhood of towns, are dangerous sources of water supply, because they are exceedingly likely to be tainted with organic matter from leaky sewers, or from graveyards. Sewage matter is rendered harmless by oxidation in percolating through the ground down to a deep spring. But the more shallow a well, the greater is the danger of drinking sewage matter in its water. The most sparkling and tasteless water may be thus contaminated. The test for it is to add a small quantity of Condy's fluid to a little of the suspected water. If the solution very rapidly becomes pale, then organic matter is present in considerable quantity.

It does not appear certain that organic matter in itself necessarily injures health. But, not to speak of the unpleasantness of partaking of dilute sewage, water thus contaminated is unquestionably dangerous, and not fit to drink, for the reason that at any moment there may be poured into it the seeds of some infectious disease. Thus, water which has long seemed perfectly good, may, if it contain organic matter, suddenly carry disease and death into nearly every house where it is used, because of the seeds from one case of infectious disease being taken into it through the sewer leakage. I could recount many recorded cases where this has actually happened, if to do so were necessary.

Water readily absorbs gases. For this reason the cistern should be placed as far as possible away from all sources of foul air, and should be kept well covered over.

Lead is sometimes taken up by water from the pipes in which it stands. The Orleans Royal family at Claremont were nearly poisoned in that manner. The presence of this mineral poison causes a yellow precipitate when *iodide of potassium* is added to the water. Whenever water has been kept long standing in leaden pipes, as by the absence of a family from home, the cistern should be quite emptied, and after that the tap should still be allowed to run for a quarter of an hour when the main is turned on, to remove that water which has been stagnant in the house pipes.

When there is any reason to fear that the water supplied to a house for drinking is impure, there are two things which can be very readily done to improve it. The first is, to boil the fluid always before drinking it; this destroys most of the animal impurities, and drives off any excess that there may be of some kinds of salts. The second plan is, to pass the water through a charcoal filter. Such filters cost very little money, and are of the greatest value. Charcoal removes at least fifty per cent of dissolved animal or vegetable matters, and about one-third of the excess of salts. In other words, it has the power of cleansing impure water, and of turning hard water into soft.

Warm drinks assist the action of the stomach, and promote the absorption of chyle. The ancient Romans drank simple hot water; we make tea, coffee, and chocolate with boiling water, and drink these as warm beverages. Thus, in our hot drinks, we get other action than that of merely the heat.

Cocoa makes a healthful hot beverage. It contains, if it is not adulterated by the addition of some form of starch, 140 grains of flesh-forming and 3934 grains of body-warming material in every pound.

Tea and coffee may be spoken of together. They are both mild nervous stimulants. There are extractives

in tea and coffee which would be poisonous if taken in sufficient quantity; but these same substances, partaken of in moderation, give a gentle stimulus to the brain and the nervous system, and arouse the mind into activity. From this point of view, tea and coffee are useful beverages to take at breakfast, when we require to be thoroughly awakened from our night's sleep, and again toward the evening, when we are wearied with the day's work. But the same properties which make them useful at these times, make them injurious if they are taken when going to bed, or in excessive quantity at any time. The substance peculiar to tea is called *theine;* and the same element in coffee, which is chemically identical with that in tea, is called *caffeine.* This substance (for though called by two names, it is practically only one) contains a good deal of nitrogen. Its value as a food, however, scarcely depends upon the nitrogen that it contains, for we do not take a sufficient number of grains to make it of any importance if it were altogether flesh-forming material. But chemists seem to have established by experiment that the result of taking a few grains of theine daily is that our food *goes further;* theine has in some way the power of preventing waste of tissue. Tea and coffee are, therefore, useful both as mild stimulants and as assistant-foods, so to speak. Professor Johnston says that half an ounce of good tea daily, which contains about four grains of theine, is a fair allowance for most grown-up persons; but that twice this quantity is almost always hurtful.

Alcoholic drinks—brandy, wine, beer, etc.—compare very unfavourably with tea and coffee as refreshing beverages, while as foods they have no value. Dr. Parkes, professor of hygiene at the Army Medical School, Netley, and author of the standard work on health, not long ago tried experiments upon this subject. He sent out "three intelligent and trustworthy soldiers,"

dressed as for a march, to walk a certain distance in a given time. Upon one day they had an allowance of rum; the next day one of coffee; and the third day one of Liebig's extract of meat. When they came back after each instalment of their march, Dr. Parkes took their temperature and the rate of their pulse; and at last they were called upon to give the evidence of their sensations after each stimulant. There was perfect agreement between the three men as to the relative value of the articles. First they all placed the extract of meat, saying that after it they felt as though they had had a meal. Next they approved of the coffee, although Dr. Parkes thought he gave it to them in too small quantities. Finally, their testimony about the spirit was that it gave them "a spurt to begin with," but after they had gone about a mile and a half they felt worse than they did before they had it. The coffee and meat extract did not produce this after-fatigue. This carefully-made experiment alone might almost settle the question as to the permanent reviving influence of alcohol. But there is much more evidence. The doctors and the men who went through the Ashantee campaign agree in saying that when alcohol was issued in the middle of a march its effects very quickly went off, and left them worse than before. "During the late Franco-German war, the German army surgeons spoke most highly of the beneficial action of hot tea and coffee as compared with alcoholic drinks in calming the mind, relieving the stiffness of limbs wearied by long marching, and preventing the ill effects of sleeping in wet clothes. They are also protective against malarious (impure air) influences, and their invigorating action is not succeeded by subsequent depression or collapse." Thus writes Dr. Clapton "On Tea." Observations have many times been made upon the capacity of total abstainers to bear fatigue; and it has never been found that they were inferior in this

respect to those who drank alcohol, though so many "unknown factors" come into any attempt to compare individuals in this way that such evidence, if it stood alone, could not be taken as of great value.

So much for spirituous liquors as aids to exertion, in practical experience. As food—that is to say, as a daily drink—they are far worse than useless. Such drinks are composed almost wholly of alcohol and water. There is no nitrogen in alcohol; therefore it yields no flesh-forming material. But it was once believed that it did act as a heat and force producing food; since it would burn and evolve heat outside the body, it was supposed that, in like manner, it would produce animal heat. But it is now made certain that, on the contrary, it reduces temperature, and decreases the body's force. It acts thus because some of the oxygen which is circulating in the blood is taken away from its proper work of combining with carbon to make heat, to combine with the alcohol; and there is not any heat produced by the mixture in our bodies of alcohol and oxygen.* Dr. Richardson, one of the most eminent of living physiologists, after making the above fact quite clear, says: "Alcohol cannot, by any ingenuity of excuse for it, be classified amongst the foods of man. It neither supplies matter for construction nor heat. On the contrary, it injures construction, and it reduces temperature. . . . That this spirit gives any persistent increase of power, by which men are enabled to perform more sustained work, is a mistake as serious as it is universal."

It is quite certain, then, that wine, spirits, and so forth, cannot be taken as foods; and to this fact must be added the statement made by the great surgeon, Sir Henry Thomson, in the following words:—"I have no hesitation in attributing a very large proportion of some

* "On Alcohol," the Cantor Lectures, by B. W. Richardson, M.D., F.R.S., etc.

of the most painful and dangerous maladies which come under my notice, as well as those which every medical man has to treat, to the ordinary and daily use of fermented drink taken in the quantity which is deemed moderate."

It is thus clear, all things being taken into account, that the best dietary is one which has no alcohol in it at all. Persons who have for years accustomed themselves to the daily use of stimulants would generally find it difficult to give them up, even though permanent good to health would be gained by so doing; but young folks, who are still free to choose what they will do in this matter, will be the better for it all their lives if they decide in their youth that they will not make alcohol a portion of their daily food. I speak quite from a scientific point of view.

Of its effects upon the brain, I must speak briefly later on. Neither have I here dealt at all with alcohol as a medicine; there are perhaps some few diseased conditions in which its habitual use is necessary. Of course, also, the positive evil result of the use of alcohol as food depends upon the quantity of spirit that there is in the beverage taken. In brandy and whisky, nearly fifty parts in every hundred of the whole are alcohol. On the other hand, claret wine has scarcely any, and table-beer only about four parts in one hundred. So that, although there is no good in drinking such things as these last, neither is there much harm in small quantities of them.

The digestibility of various kinds of solid food has been studied, partly by a French physician who could bring up his food at any time after eating it that he chose, partly by doctors who have had the care of persons with wounds in their stomachs. The most useful case of the latter kind was that of a young Canadian, named Alexis St. Martin. He received a gun-shot in the stomach, and the wound never closed again. In process of time, a

fold of the lining membrane of his stomach fell like a curtain over the hole; and Dr. Beaumont, his physician, could watch the whole process of digestion by pushing the flap aside. The following table gives some of the results of his observations:—

| | | h. | m. |
|---|---|---|---|
| Boiled rice | was digested in | 1 | 0 |
| Bread and milk | ,, ,, | 2 | 0 |
| Apple dumpling | ,, ,, | 2 | 30 |
| Oysters, raw | ,, ,, | 3 | 0 |
| Roast beef | ,, ,, | 3 | 0 |
| ,, mutton | ,, ,, | 3 | 15 |
| Boiled beef | ,, ,, | 3 | 30 |
| Potatoes | ,, ,, | 3 | 30 |
| Bread, buttered | ,, ,, | 3 | 45 |
| Fowl boiled | ,, ,, | 4 | 0 |
| Veal ,, | ,, ,, | 4 | 0 |
| Pork roasted | ,, ,, | 6 | 0 |

From this list, persons who suffer from indigestion may obtain useful hints. This disease has very many symptoms, which I need not repeat here. No one but a doctor can decide whether certain feelings arise from the stomach itself, or from the liver, or from the heart. or some other neighbouring part. Those, however, who suffer pain after eating generally have some failure on the part of their stomachs to provide against. Perhaps they have an insufficient supply of gastric juice, or the mucous membrane of the stomach is in a delicate state, or there are muscular spasms. Whatever the cause may be, common sense teaches that they should select the foods which are most easily converted into chyme. Roast pork, green vegetables, new bread, and pastry, are therefore especially to be avoided.

Indigestion may be caused by eating too much; both because the stomach is thus over-distended and cannot perform the churning movement which we know it has

to make in digesting, and because the supply of gastric juice is only intended for *enough* food, and when too much is taken, it cannot be properly acted upon by the stomach. Pain after eating is caused also by swallowing food without first thoroughly crushing it up between the teeth, and mixing it with the saliva. The teeth are so necessary to the digestion, that false ones for people who lose their own are very desirable. Cold water, although the best of all drinks, may cause indigestion when taken in too great quantity, by lowering the heat of the stomach. Eating too frequently, as well as too much at a time, will cause indigestion. The stomach is not an organ intended, as is the heart, to be constantly at work; it requires a short period of rest after it has undergone exertion. We see by the above table that most articles of food take between three and five hours to digest. Thence, we may gather that *at least* four hours should elapse between one full meal and another. Solomon puts an important lesson upon this point shortly:—"Excess of meats bringeth sickness."

Some persons are made unwell by eating particular articles of food, which to most people are harmless. Some are thus affected by various kinds of shell-fish, others by eggs, or by fruit. Dr. Elliotson had a patient who could digest hard salt beef, but who suffered dreadful pain if she took a single strawberry. The secretary of Francis the First of France could not eat bread, and there are several cases recorded of people who had to avoid apples. Experience is the only guide for us as to what will disagree with us; and, for this reason, hints only, not definite directions, can be given for selecting the daily food of individuals.

The digestibility of food is increased by its being cooked; it becomes more easily masticated, and much more agreeable to the taste. But meat is often wasted in cooking, and its nutritive parts actually thrown away,

for want of the simplest knowledge of the principles of cookery.

When meat is roasted, or boiled for eating, it requires to be treated in a very different manner from when it is boiled to make soup, with the intention of throwing away the meat as useless. In the former case, the object of the cook must be to keep all the flesh-forming elements and the fat in the joint; in the last case, she wishes to draw these properties out of the meat into the water.

Meat, as we know, contains a nitrogenous substance called fibrin, which is of the same character as white of egg. The white in an uncooked egg is a thickish liquid; but when a boiled egg is brought to table, we find that the white is quite a firm tough substance—in other words, white of egg is coagulated by heat. The same thing happens when the same sort of substance in meat is subjected to the action of fire. When, therefore, it is wished to *keep in* the juices of a joint, it should be exposed at once to a good deal of heat, because the albumen in its outer part is thus immediately coagulated, and forms a coating which prevents the juice from soaking out. Thus, if it is to be roasted or broiled, a piece of meat should be put into a well-heated oven, or over a good fire; if it is to be boiled, the water should be boiling when the meat is put in. But if broth is to be made, the meat should be put into cold water and gradually brought to the boil. By this means, the albumen is not suddenly coagulated into a covering over the outside; but the juice is drawn out into the water by degrees. It is of the highest importance to remember this fact when making beef-tea, upon which an invalid is to be supported.

An excellent soup is made for the sick by joining together the knowledge just gained, and a fact which we know about the gastric juice. A pound of lean beef is to be cut into dice, and put into a pint and a half of cold water; to this is to be added twenty drops of dilute

hydrochloric acid, the acid of the gastric juice; and the vessel containing these ingredients is to be put into the oven, or upon the hob, and slowly brought to blood heat. By this means, a kind of artificial digestion of the meat is carried out, and the sick patient obtains more nourishment in a small quantity of fluid than he can do in any other way.

The most important point to remember in preparing this soup is that the temperature must not rise above that of the body; when the finger is put down into the jar, there should scarcely be any warmth perceptible to it in the fluid. If the heat becomes greater than this, the process is stopped, and the meat wasted.

*Obesity* is the scientific name for over-fatness. Excessive fat generally extends to the internal organs of the body, and produces many diseases. The heat-forming foods are also the fat-producers. When more carbon is taken than can be used up in the system, it is stored up as fat. Hence, the plan adopted by the famous Mr. Banting to reduce the uncomfortable size of his patients was simply to keep out of their diet all starches and sugars. I mention this subject chiefly to warn my readers who may think themselves too stout not upon any account to attempt to reduce their size by the excessive use of acids. There have been cases in which death has actually resulted from this mistaken practice; and it is to be feared that injury is not unfrequently done in this way to the delicate coats of the alimentary passages. The scientific plan of avoiding sugar, butter, cream, potatoes, and beer, will be found far more effectual, as well as harmless.

Other applications of the knowledge gained here of food and digestion, you will be able to make for yourselves. I must conclude the subject now, once more reminding you that it is with temperance that we may enjoy the fruits of the earth in due season.

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TRIVANDRAM.

# CHAPTER VIII.

## SECRETION AND EXCRETION—THE LIVER.

ONE of the difficulties which we meet in learning a new subject is that we must inevitably sometimes find terms employed the precise meaning of which has not been made quite clear to us. In these chapters it has been necessary to speak of the *secretion* of saliva and gastric juice, and of the *excretion* of carbonic acid gas by the lungs; but the opportunity of explaining the exact meaning of these words has only now arrived.

The Germans, a wiser people than we are in that respect, make their scientific terms out of their mother tongue, so that the words convey some meaning to everyone. Our scientific names are constructed from the Latin and Greek languages; and when we know what words from these languages have formed the roots of our own terms we have obtained a clue to the real meaning of the latter. The word secretion comes from the Latin *secernus*, which is "to sift or separate;" excretion comes from *cerno*, "I sift," and *ex*, "out off."

Both words, in physiology, are used to express the separation or sifting of some substance from the blood. The distinction between them is that a secretion is separated from the blood to be used again in the system for some special purpose, while an excretion is effete waste matter, and is thrown out of the body entirely. For example: the bile is a *secretion*, obtained by the liver out of the blood, and used to complete the digestion of

the food; the perspiration is an *excretion*, separated by the sweat-glands from the blood, and cast out upon the surface of the skin to evaporate into the air, or to be washed away with water.

All those parts of the body which are engaged in secretion and excretion are termed *glands*. That is their family name; but, of course, they have individual names also. Just as we might say of a whole group of persons, "Those are the Smiths," but when we wished to refer to any of them more particularly we must add the first name to distinguish one from another, so all secreting and excreting organs are called glands, but each one or each kind has its own name as an individual also. Thus the liver, the kidneys, the pancreas, and various other organs, each having a distinctive name, are one and all glands, because they all perform this work of separating something from the blood.

There are a great number of glands in the system, varying in size from the liver, which weighs about four pounds, to the small glands in the intestine, which cannot be seen without a microscope. They differ greatly from each other, also, in shape, and in the details of their construction. But notwithstanding these diversities, all glands, from the smallest and simplest to the largest and most complex, have the same fundamental structure. To illustrate this, we may think of the difference between a gentleman's mansion and his labourer's model cottage: there is not the least resemblance between the two buildings, neither in outer appearance, nor in the number or the shape of the rooms and their furniture inside; yet they are nevertheless both houses, both intended for people to live in, and both made of identical material. Similarly, all glands, however diverse they may appear to be, are intended to answer the same purpose, and are, so to speak, built out of identical material. They consist essentially of a membrane (or fine skin), which is on

one side covered by a layer of exceedingly minute bags, called *epithelial cells*, while it rests upon capillaries on the other side. The epithelial cells have the power of drawing the peculiar secretion of the gland out of the blood that is circulating through the capillaries. The moist skin covering the inside of our lips is a ready example of this secreting membrane, with epithelial cells forming one

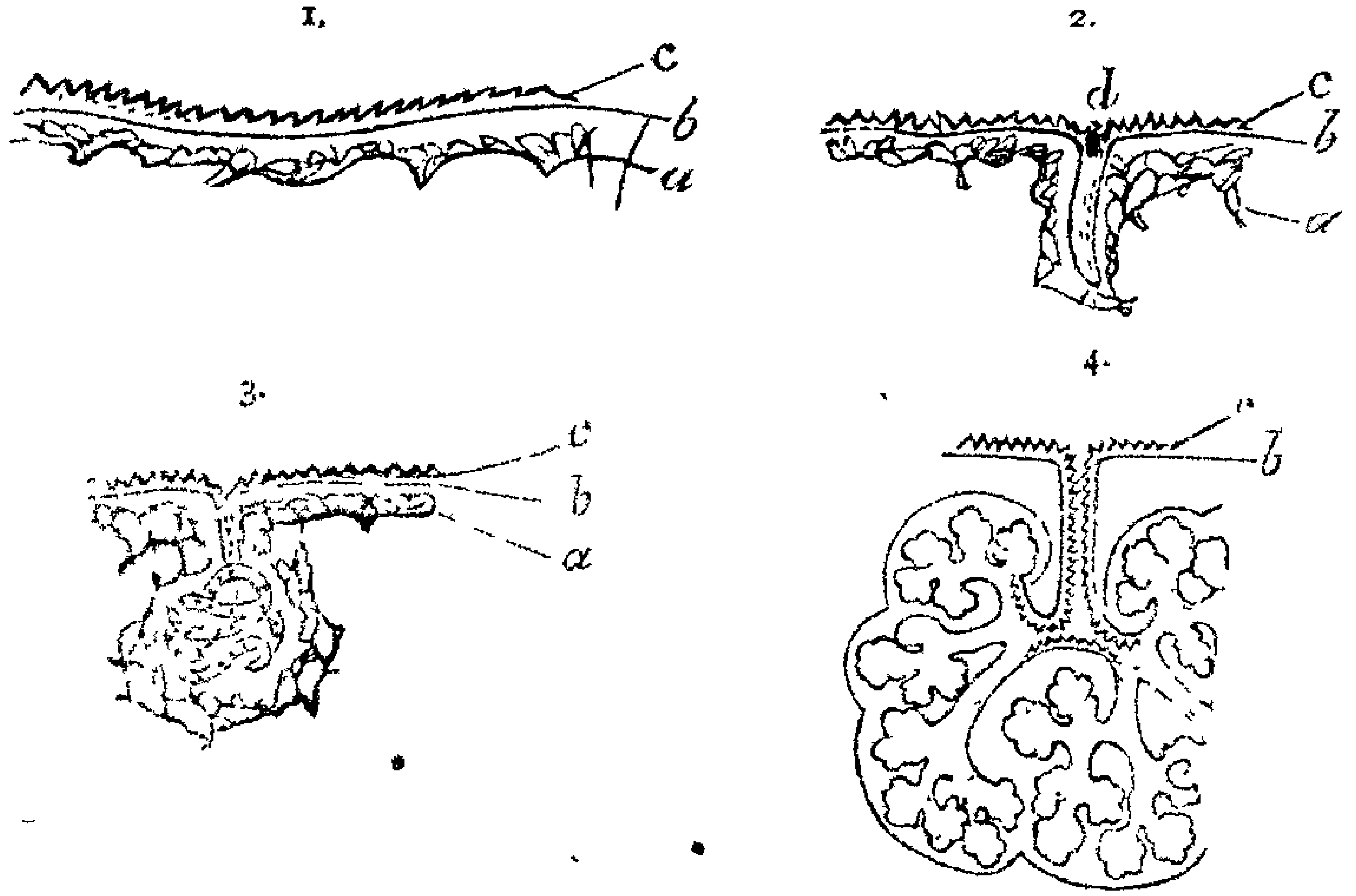


*Fig.* 10.—The Structure of Glands.

1, A diagram to show the plan of a secreting membrane; *c*, layer of epethelial cells; *b*, basement membrane; *a*, capillary vessels. *a*, *b*, and *c*, indicate the same in each figure. 2, The simplest form of gland, a mere depression of the membrane *d*, with blood-vessels surrounding it. 3, A more complex gland, with coiled tube E; the sweat-glands are of this kind. 4, Part of a racemose gland, such as the salivary glands are.

side of it, and resting on the other side upon capillaries. To make a gland, such a membrane is more or less twisted and convoluted. The simplest form of gland is merely a pouch of the membrane, with the epithelial cells inside, and the capillaries surrounding it outside; and the same membrane, elaborately twisted, branched, connected by tubes, formed into lobules, and so on, is still the essential part of the most complex glands. Fig. 10 will help in making this explanation understood.

There is no distinguishable difference of any kind between the epithelial cells of any one gland and those of any other; and it is very wonderful that these apparently identical cells should elaborate from one and the same fluid such diverse secretions in the different glands. Why, and how, the cells in the liver make bile and not gastric juice, those in the stomach make gastric juice and not sweat, those in the skin make sweat and not saliva, and so on, we do not know and we can hardly imagine. It is one of those mysteries of life which we may never really understand, though we know them to exist.

*The liver* is the largest gland in the body, weighing about four pounds. It lies on the right side of the abdomen, covered by the lower ribs, and touching the diaphragm. The liver is an exceedingly complex gland; indeed, its minute structure is not yet thoroughly and certainly made out by anatomists. It is, as was mentioned in connection with the subject of digestion, the organ which separates *bile* from the blood; and as the bile is used for the completion of the digestion of food, the liver is, of course, a *secreting* organ. The remainder of this chapter will deal with the secreting glands only, leaving the excreting organs to form the subject of the next chapter.

The smallest subdivisions of the liver are called its *lobules.* They are roundish, but many-sided, little masses of substance, about the size of a mustard-seed. Their structure and arrangement are a little complex; but with attention the description which follows will become clear.

Two different large blood-vessels—the one an artery, the other a vein—enter the liver side by side (see Fig. 11). At the same spot is also seen entering the substance of the liver a third tube, but this is not a blood-vessel; it is called the *hepatic duct* (*i.e.* the liver pipe), and is the canal through which the bile comes out of the liver after it has been secreted within the organ. If we follow the course of the hepatic duct about an inch and

a half outwards from the liver, we find that it forms a junction with two other tubes, one of which leads up into the gall-bladder, and the other, being joined by the duct of the pancreas, opens straight into the duodenum. The bile is secreted by the liver unceasingly, and all of it passes out of the organ through the hepatic duct; but

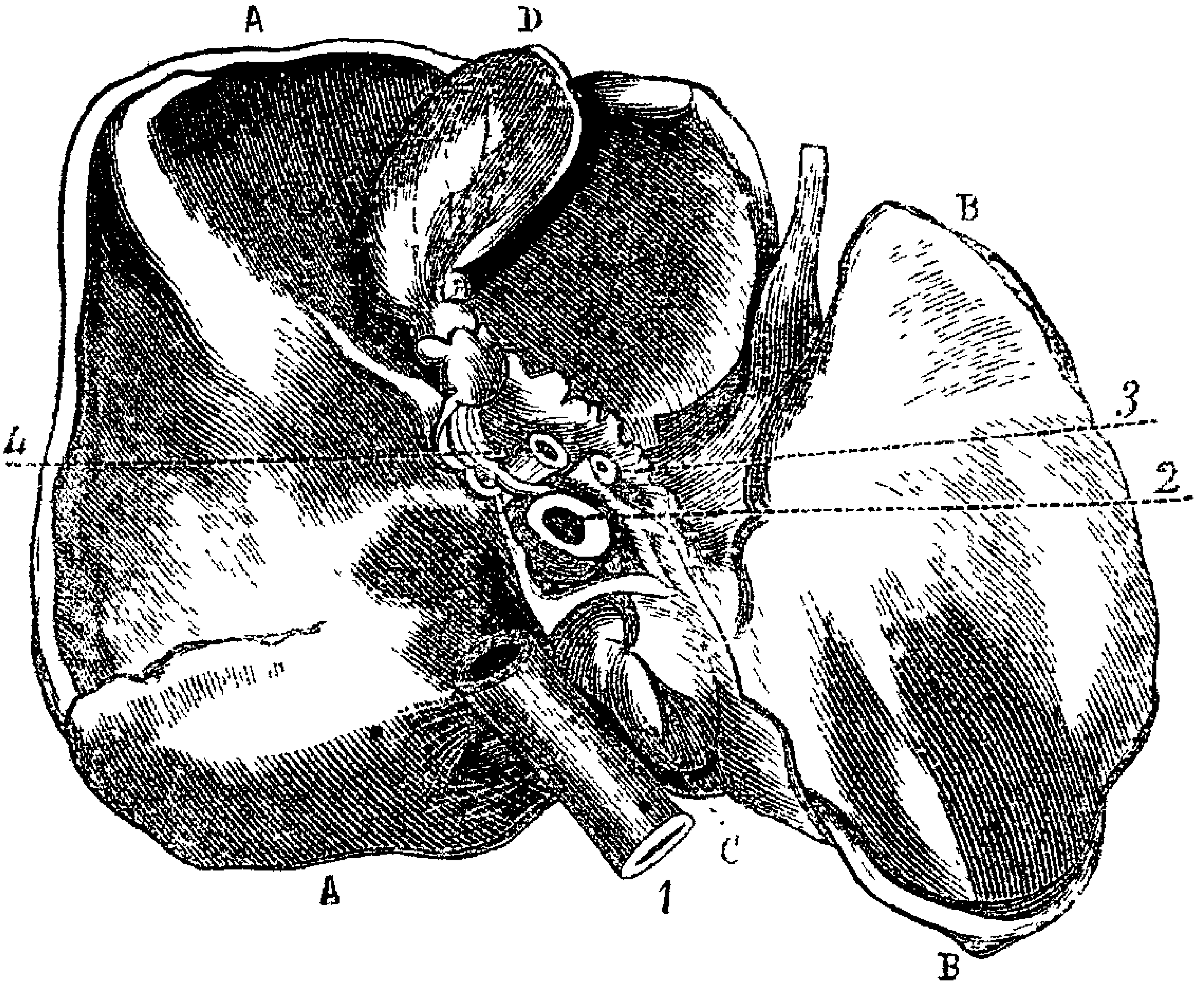


*Fig.* 11.*—UNDER SURFACE OF THE LIVER.

A, Right lobe; B, left lobe; C, lobulus spigelii; D, the gall-bladder; 1, the vena cava inferior, which passes over the liver in a groove at this spot: both its ends are cut; 2, the portal vein; 3, the hepatic duct; 4, the hepatic artery.

that which is secreted in the intervals when digestion is not proceeding goes through the one tube to be stored in the gall-bladder until it is required, while that which comes from the liver at the time when chyme is being passed through the pylorus goes down at once through the other tube into the intestine to perform its part in digestion.

* From Bourgery.

The gall-bladder is that pear-shaped bag which can be seen in Fig. 11, resting upon the liver. It becomes filled with bile by degrees when digestion is not proceeding. When food enters the duodenum, its presence there acts as a (reflex) stimulus to the muscular coats of the gall-bladder, and they, contracting, push the bile down, and through the narrow opening of the duct into the intestine.

The other two tubes which are seen entering the liver at the same place with the hepatic duct are, I have said, an artery and a vein.

The spot where they all three penetrate into the organ was called by the old anatomists the gate, or *porta*, of the liver; and hence the vein which enters there is named the *portal* vein (vena portæ). The blood which the portal vein carries into the liver is that which has already circulated through the capillaries of the spleen, the stomach, and the intestines. Those capillaries join together so as to make several good-sized veins, which unite into the portal vein. It is doubtless out of this blood that the liver takes the bile.

The artery which enters at the same place is called the *hepatic* (or liver) artery. The blood which is carried into the organ by this vessel is pure arterial blood, coming direct from the aorta. This blood supplies nutrition for the coats of the vessels, and the other tissues of the liver.

The *portal vein*, the *hepatic artery*, and the *hepatic duct*, as they all enter the substance of the liver together, also keep together throughout their course, dividing generally side by side.

Let us follow more particularly the "distribution," as anatomists call it, of the portal vein, keeping in mind, however, the fact stated in the last sentence.

This blood-vessel, having entered the liver, divides and subdivides into a number of smaller tubes, just

ıs arteries do, just as the hepatic artery does in that ame organ; only, you know, it *is* a vein, not an artery, ecause it is made by the joining together of capillaries, nd because it is conveying the blood which has passed hrough those capillaries back toward the heart.

By this dividing and subdividing, the portal vein nakes a great number of small vessels, which are called he INTER-*lobular* veins (*i.e.* the veins *between the lobules*), ecause they form a network around each lobule, marking it off from the others. Indeed, each of those little nasses is, as it were, wrapped up by a network of these ubdivisions of the portal vein, called inter-lobular veins.

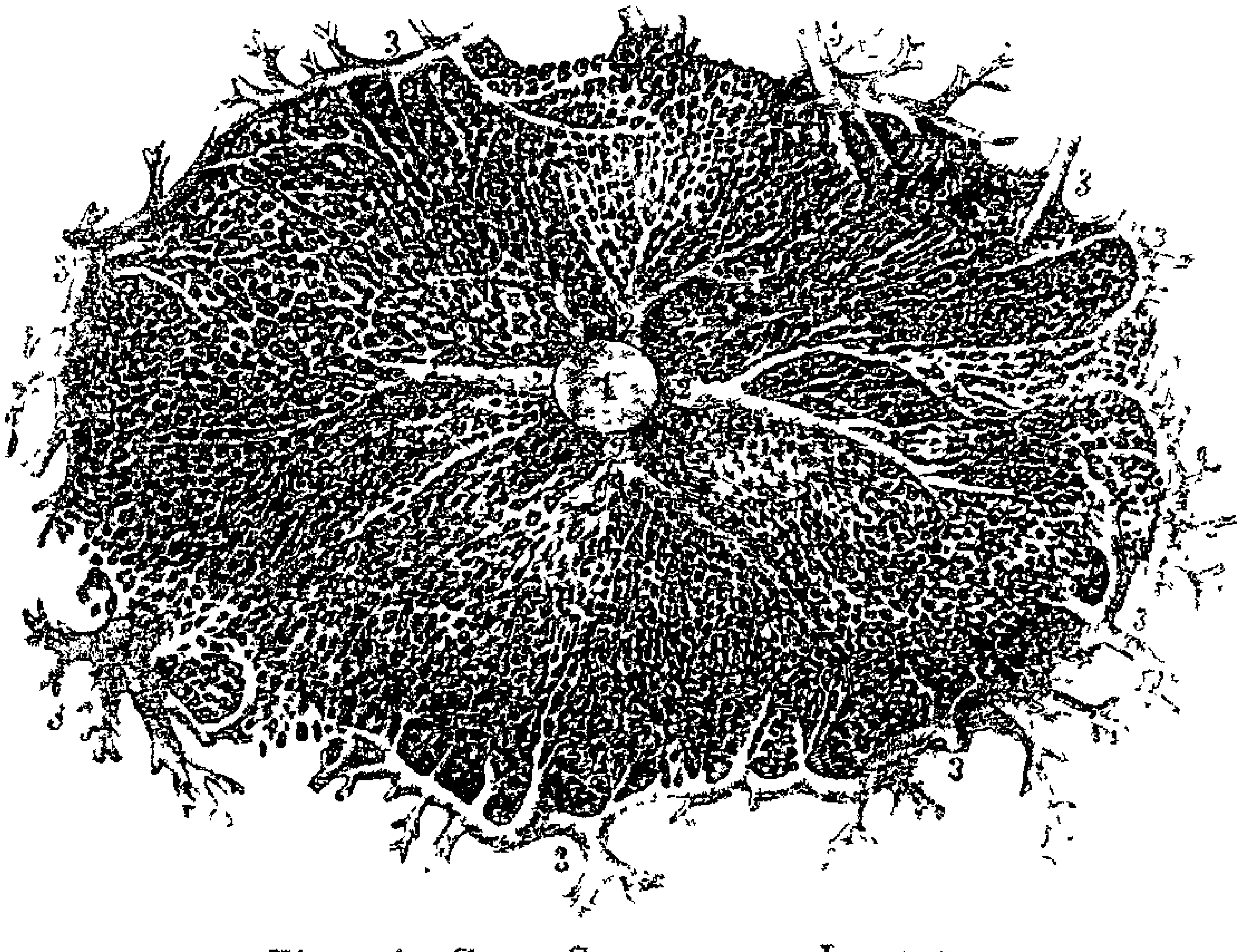

*Fig.* 12.*—CROSS SECTION OF A LOBULE.

The *intra*-lobular vein; 2, its branches through which the blood enters it from the surrounding network of capillaries; 3, *inter*-lobular branches of the portal vein, entering the lobule and forming the capillary network.

From this network between the lobules vessels enter nto the substance of each lobule, and there form a very ense capillary network. Fig. 12 represents a lobule cut

* From Kirkes, after Sappey.

down through its centre, and magnified sixty times its real size. You see there how close the network of capillaries is within the lobule. Of course the coats of those tiny vessels must be exceedingly thin; and while the blood is in them it is that the peculiar secretion of the liver, the *bile*, is formed. All the interspaces of that network of capillaries are occupied by the *liver cells*, those exceedingly minute bladder-like bags which are, as was said in the early part of this chapter, the essential agents in the work of secretion. As the blood passes through the capillaries inside the lobules, the liver cells, by which it is then surrounded, draw the bile out (as well as work another change in it, which will be referred to presently), and the blood goes on its way purified from the bile, while the secretion passes through the branches of the hepatic duct to reach the gall-bladder, from whence it enters the duodenum, and aids in the digestion.

Exactly how the hepatic duct ends in the liver is still a disputed point. Its subdivisions can, however, be traced distinctly quite up to the circumference of each lobule; so that the liver cells can discharge their contents into the final branches of the duct, through which the bile then travels until it reaches the duct itself, and is passed, according to circumstances, either into the gall-bladder or into the small intestine, as described on p. 88.

That the blood is purified for the rest of the body by the removal of bile from it is shown by the illness (called jaundice) which results when the secretion is interrupted.

Now return your thoughts to the structure of the lobule. We have seen the portal vein break up into inter-lobular veins, and these, prolonged into the lobules, making a dense capillary network with liver-cells in the meshes thereof. The blood in these tiny vessels is, therefore, the *portal* blood. The blood of the *hepatic artery*, however, here mixes with the portal blood; the

inal branches of that artery becoming mingled, apparently, with the final branches of the portal vein. Thus the blood which comes out of the lobule is a mixture of that which has given up the bile and that which has supplied the organ with nutrition for its tissues.

The capillary network in the lobules gradually joins together to make rather larger trunks, as capillaries always do, and finally, all their contents get poured into one small vein which runs through the very centre of each lobule. It is marked 1 in Fig. 12. These vessels in the centre of the lobules are called the INTRA-*lobular* veins (literally, *inside the lobule*).

Each lobule is placed by its lowest side upon a tiny vein, called SUB-*lobular* (*i.e. under the lobule*). The intra-lobular vein runs down and opens into the sub-lobular vessel (Fig. 13).

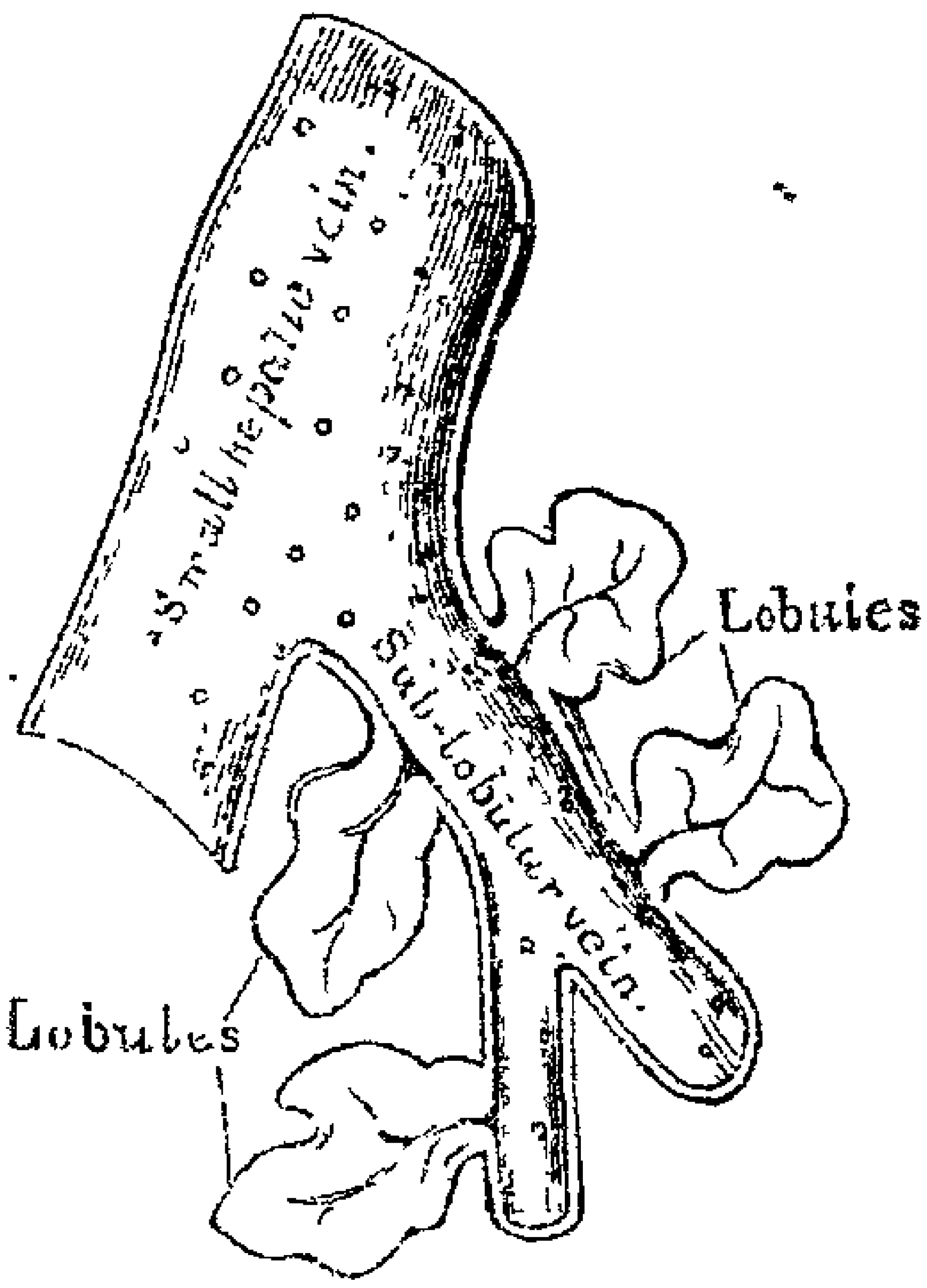


*Fig.* 13.

A diagram showing the position of the lobules of the liver on the blood-vessels.

Several sub-lobular veins join together to form the main branches of the *hepatic veins*, and these, continually uniting after the manner of veins, eventually form two or three trunks (called the hepatic veins), which open into the *vena cava*, where that great vein lies upon the liver. Through it the blood, as you know, is carried straight to the right side of the heart.

The liver secretes (as I mentioned in passing on page 91) another substance besides bile. This is a kind of starch named *glycogen*, which is very readily turned into sugar. In carnivorous animals, which eat no starchy food, the liver still secretes glycogen, although the quan-

tity produced is larger when starchy foods are eaten. The sugar is probably carried away by the blood to the heart and lungs to form animal heat by being united with oxygen.

The quantity of bile secreted in twenty-four hours is about a pint and a half or two pints.

The proper performance of the work of the liver is of much importance to the general health. Unfortunately, "liver complaint" is one of the most common of diseases; and although the hygiene of this organ is not so directly under our control as is that of many others, there is yet no doubt that its disorder is very often the result of unhealthy habits. The disease is really congestion—over-engorgement with blood—of the liver; the result of which condition is the sense of fulness and weight on the right side, the slight pain on pressure, the aching beneath the shoulder-blade, the sickness, headache, bitter flavour in the mouth, and lassitude, which make up "a bilious attack" and "liver-complaint." Among its most frequent causes are the use of very highly seasoned food, habitual over-eating, and the excessive drinking of alcohol. Dr. Prout declared that nine out of ten well-to-do persons eat too much every day. The witty Sydney Smith calculated that between ten and seventy years of age he had eaten and drunk forty-four one-horse waggon-loads of meat and drink more than would have preserved him in life and health; a mass of nourishment worth seven thousand pounds sterling, and sufficient to have supported three other persons. More seriously, Dr. Budd, in his standard work on *Diseases of the Liver*, says—"Amid the continual excesses at table of persons in the upper and middle classes of society, an immense variety of noxious matters find their way into the portal blood that should never be present in it, and the mischief which this is calculated to produce is enhanced by indolent and sedentary habits. The

consequence often is, that the liver becomes habitually gorged. The same, or even worse effects, result in the poorer classes of our towns from their inordinate consumption of beer and gin."

The physiological details given above enable us to see how much the liver must be affected by errors in diet, and especially errors as to quantity; for we have seen that the blood which circulates through the liver comes directly from the coats of the stomach and intestines, charged with some of the results of digestion. If these are excessive in quantity, the engorgement of the veins of the liver is the almost certain consequence. Thus, although the evil effects upon health of over-eating are not so much talked about as those of a starvation diet, yet they are almost equally great.

When the mischief is done, and when the overloaded liver causes sickness and loss of appetite, the sufferer should accept the symptoms as a lesson from nature, and, instead of goading the digestive organs with drugs and tempting them with delicacies to resume their work as early as possible, let them rest until the desire for food returns with the capacity for its complete digestion.

As soon as the first symptoms have gone off, exercise of the body and rest of the brain are the best remedies to take. The popular medicine, "a blue pill and a black draught," is an unsafe one, likely to be exceedingly injurious if had recourse to very frequently. Blue pill is made of mercury, and this is so dangerous a drug that wise physicians have declared their distaste for prescribing it, even for those complaints over which it alone has much influence. The remedy is often truly worse than the disease.* This, therefore, is not a medicine to

* As these chapters are intended to be practically useful in everyday life, I will add that the best liver pill, for ordinary mild attacks of passive congestion, is one of *podophyllum and henbane*. For example, half a grain of resin of podophyllum, three grains of

be heedlessly and needlessly swallowed; and I must not dismiss the point without adding a word of warning against the frequent dosing of little babies with grey powder, which is a preparation of mercury.

Never buy quack medicines of any kind: they are frequently compounded by men equally ignorant and unscrupulous. The ingredients of them are kept secret, and our laws do not require of their advertising makers any kind of proof of scientific knowledge. Somebody's loudly-puffed liver pill may, therefore, be a dangerous drug in unsafe quantities, put together by an impostor utterly ignorant of the human structure, and of the causes of its sufferings in the diseases he pretends to cure. As Crabbe, whose own medical education enabled him to see the danger of tampering with the delicate mechanism of life, wrote forcibly:—

> . . . "Quacks are gamesters, and they play
> With craft and skill to ruin and betray;
> With monstrous promise they delude the mind,
> And thrive on all that tortures human kind;
> Void of all honour, avaricious, rash,
> The daring tribe compound their boasted trash;
> For soul or body no concern have they;
> All their inquiry, 'Can the patient pay,
> And will he swallow pills until his dying day?'"

*The pancreas* is a secreting gland, next in size and importance to the liver. Its secretion, which is called the pancreatic juice, aids in digestion, as already explained. This fluid is carried out of the organ through the pancreatic duct, which joins into the bile duct, so that the two tubes form one, and the two secretions

extract of henbane, and six grains of rhubarb powder, mixed by the chemist into two pills, of which one or both may be taken at bed-time.

enter the duodenum together. The pancreas lies at the back of the trunk, just behind the stomach.

The *salivary* glands, the *intestinal* glands, and the *gastric* glands, have all been more or less fully spoken of in previous chapters.

Among the most curious and obscure organs of the body are the so-called *ductless glands.* The blood goes into these organs, and returns from them again, and this must happen for some purpose. But they have no pipes (or ducts) through which any secretion is passed out of them. It is nearly certain that they are true glands, because they have the essential structure of a gland, excepting only that they have no duct; but the commonly received opinion as to their office—namely, that they aid in elaborating the corpuscles of the blood—is little more than a conjecture. The principal ductless glands are the *spleen*, the *thymus* and *thyroid* glands, little masses of substance found in the neck, and two curious little bodies that are placed like caps on top of the kidneys, and are called the *supra-renal capsules.*

## CHAPTER IX.

### EXCRETION—THE KIDNEYS AND SKIN.

THE three great *excreting* organs of the body are the lungs, the kidneys, and the skin. These all separate from the blood and pass out of the body the same waste matters, though in different proportions. The chief excreted substances are *carbonic acid* (produced, as you already know, by the chemical action of oxygen upon carbon in the body), *water* (hydrogen and oxygen), and *urea.* The last-named is a solid substance, and is the product of that using-up of the nitrogen of the tissues which necessarily happens in the performance of every vital function. The kidneys pass off the most urea, which is dissolved in a large quantity of water; the lungs pass off the most carbonic acid; and the skin excretes a very considerable quantity daily of both water and carbonic acid, but not very much urea. Thus there is in function a very close association between these three organs.

The lungs have already been studied; we can now, therefore, proceed to consider the physiology of the kidneys.

The shape of the human kidney is exactly similar to that of a bullock's or sheep's. There are two kidneys, and they are situated at the back, in the loins, with the concave part turned inwards. A narrow pipe runs downwards from the curved-in centre of each one, and both of those tubes open below into a bag of thin muscle and

skin which lies in the middle of the pelvis, at the bottom of the abdomen. That bag is the *urinary bladder*; the tubes which go down into it from the kidneys are *the ureters*. Another tube runs down from the bladder and opens to the outside of the body; so that the kidney is thus placed directly in communication with the exterior.

Following the ureter up into the kidney, we see (as in Fig. 14) that the tube widens out, so as to form a space

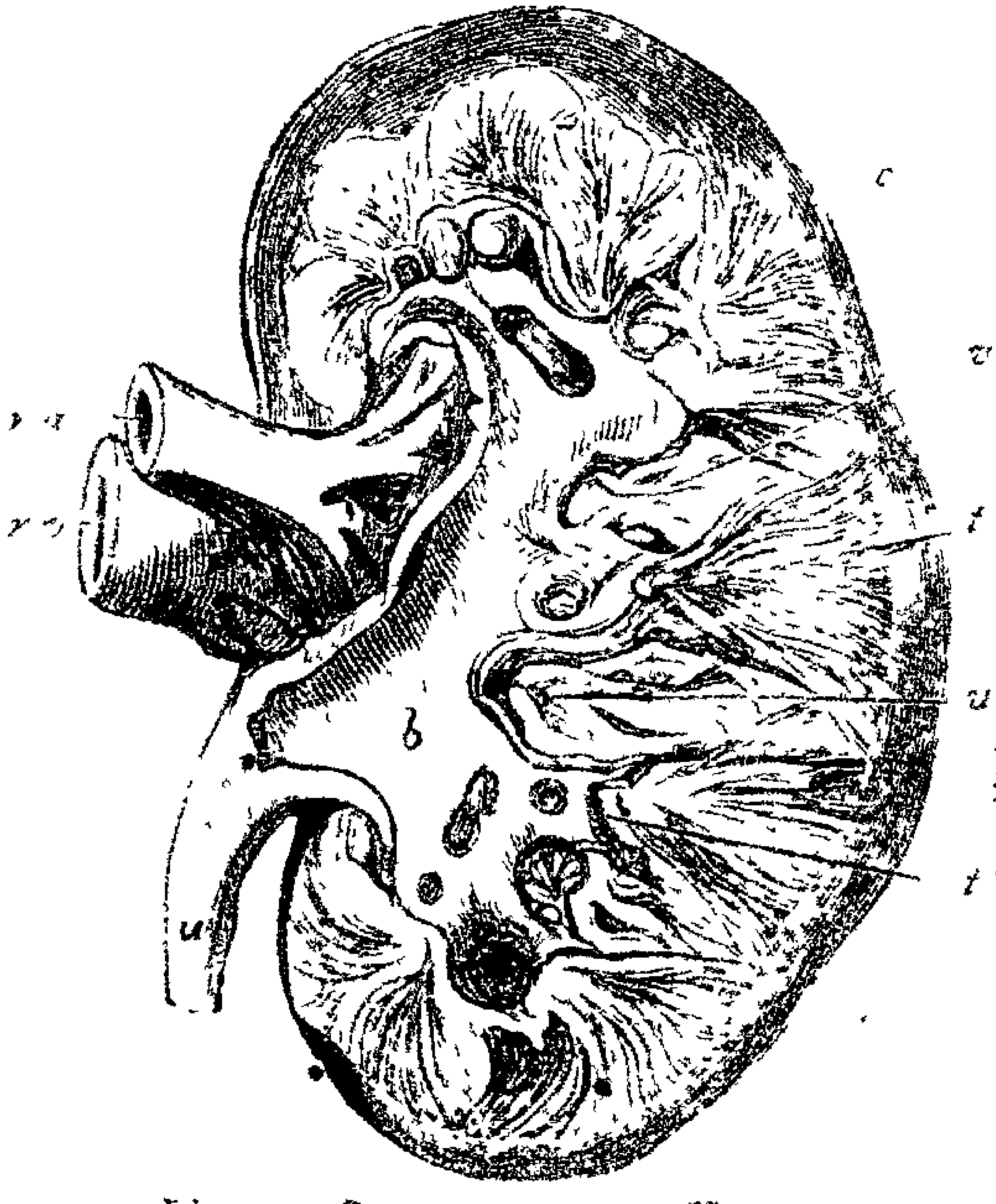


*Fig.* 14.—SECTION OF THE KIDNEY.

*u*, The ureter; *b*, the pelvis, with the pyramids projecting into it; portions of the medullary substance of the kidney are removed, to show *v*, the dividing blood-vessels; *r a*, the renal artery; *r v*, the renal vein; *c*, the cortical part; *t*, the pyramids of the tubules.

inside the organ. This space is called the *pelvis* (*i.e.* basin) *of the kidney*. Into it there project several little masses, called the *pyramids*, in consequence of their sugar-loaf shape.

If the kidney be cut longwise, right through its centre, the naked eye can readily see a difference between

the interior and the outer portions; this is something like the difference in texture between the pith and the hard rind of some flowers' stems (such as the sunflower), and names have been given to the parts of the kidney as though with this idea. The outer is called the *cortical* part, which really means the bark, and the inner is termed the *medullary*, or marrow part. The medullary portion is found, under the microscope, to consist of the bases of the pyramids.

And what do you think the pyramids prove to be made up of? Of nothing else but hundreds and hundreds of exceedingly tiny pipes. If that part of a pyramid which projects into the pelvis of the kidney be examined with a magnifying glass, it is seen to be studded with the little open mouths of something like a thousand minute tubes. There are about a dozen pyramids—so that there are at least twelve thousand tubes—in each kidney. They are called the *tubuli uriniferi*, and are lined all along with those epithelial cells which are the essentials of secretion.

If you have comprehended this description, you will see how any fluid passing through those tubes must flow on, down the ureter into the bladder, whence it can leave the body.

Now, the little tubules really do the work of excretion; to understand just *how* they do it, we must follow them backwards.

Tracing the tubes backwards, from the pelvis of the kidney toward its cortical part, the anatomist sees them divide and subdivide, and finally become very much twisted and interlooped with one another, back in the cortical part. Nearly every distinct one of these twisted tubes ends, at last, in the cortical part, in a dilated end, or, as it were, in a bulb stuck on the tip of the tube. The bulb is lined with a layer of the epithelial cells which, you remember, are necessary for secretion or excretion; and it is called, after its discoverer, a *Malpighian capsule* (Fig. 15).

The *renal artery*, the blood-vessel of the kidney, enters the organ at its concave part, and its branches pass down between the pyramids to the cortical portion. There they divide into a great number of still smaller branches; and *one of these small branches* of the renal artery *pierces each of the Malpighian capsules, and inside these dilated ends of the tubules the blood-vessel breaks up into a tuft of capillaries* (see Fig. 15).

Now, you see, the blood in the kidney is in the position necessary for a secretion to be removed from it: the fluid is in very delicate-walled capillaries, and epithelial cells are only separated from it by a thin membrane.

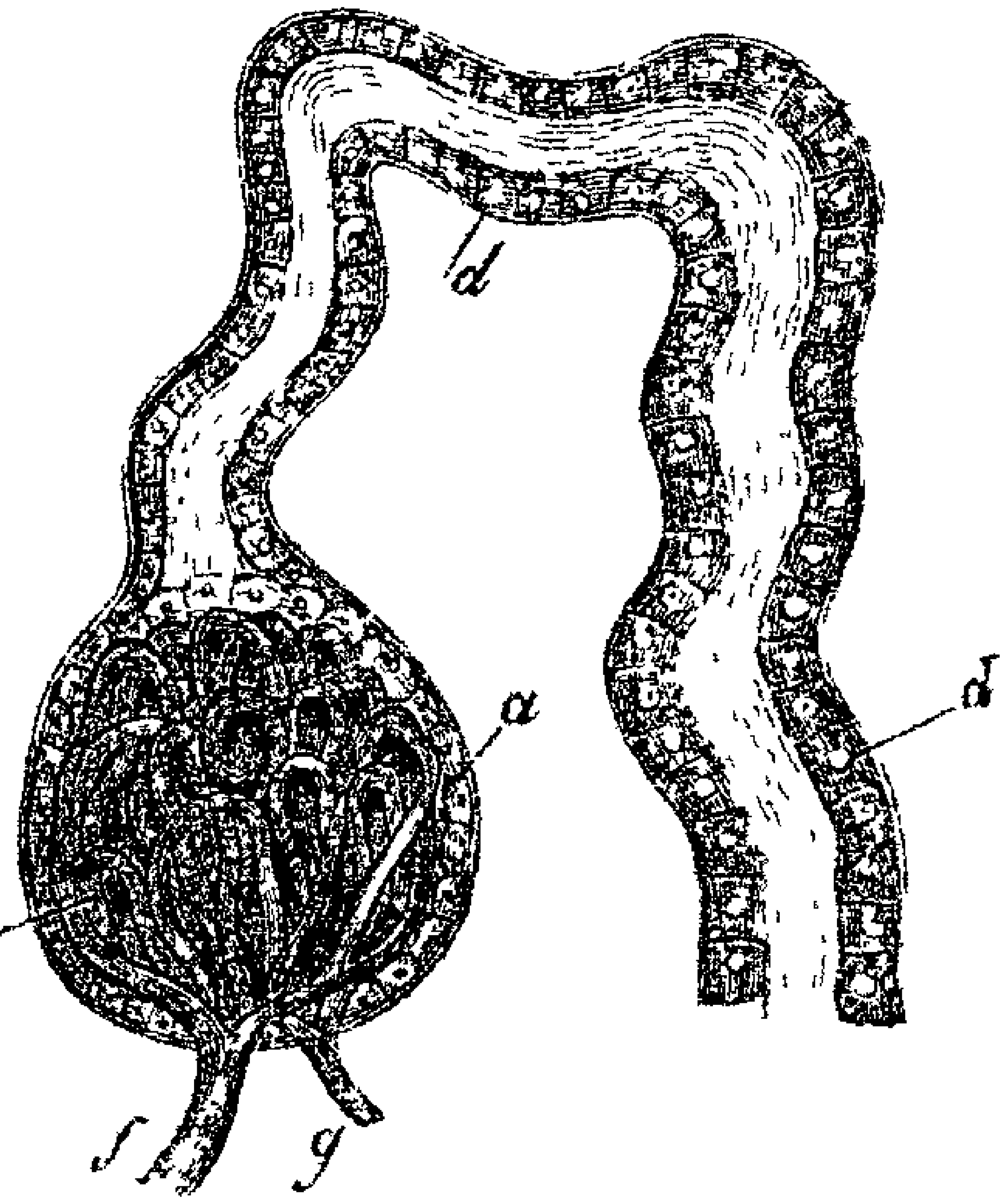


*Fig.* 15.—A MALPIGHIAN CAPSULE, with a portion of the tubule to which it belongs; *f*, the artery, entering the capsule, and forming *a*, the capillary bunch; *g*, the vein; *d*, the epithelial cells.

Accordingly, while the blood is in this position, the excretion of the kidney, the urine, is strained through the membrane, passes along the tubuli uriniferi, out at their opposite ends through the pyramids into the pelvis of the kidney, down the ureter into the bladder, and so, before very long, out of the body. This is how the kidneys perform their work of excreting much water, with much nitrogenous waste and various saline effete matters dissolved in the water.

The tuft of capillaries into which the renal artery divides in each Malpighian capsule is called a *glomerulus*. The capillaries unite in the capsule to form a vein, which leaves the bulb near where the artery entered (Fig. 15);

but instead of this vein at once joining into another to make a larger tube, as it might be expected to do, no sooner does it get outside the capsule than it divides again to make a network of capillaries of its own, which surrounds the same tubule from the terminating dilation of which the vein had just emerged. A short study of Fig. 16 will aid in the comprehension of this arrangement. It is obvious that the purification of the blood from urea may be finally completed while it circulates through these second capillaries, after leaving the Malpighian capsule; for the tubules are lined right along with secreting cells. No doubt this is really the case; not only the capsule in which each tubule ends, but also the whole length of the tubule itself is engaged in the work of excretion.

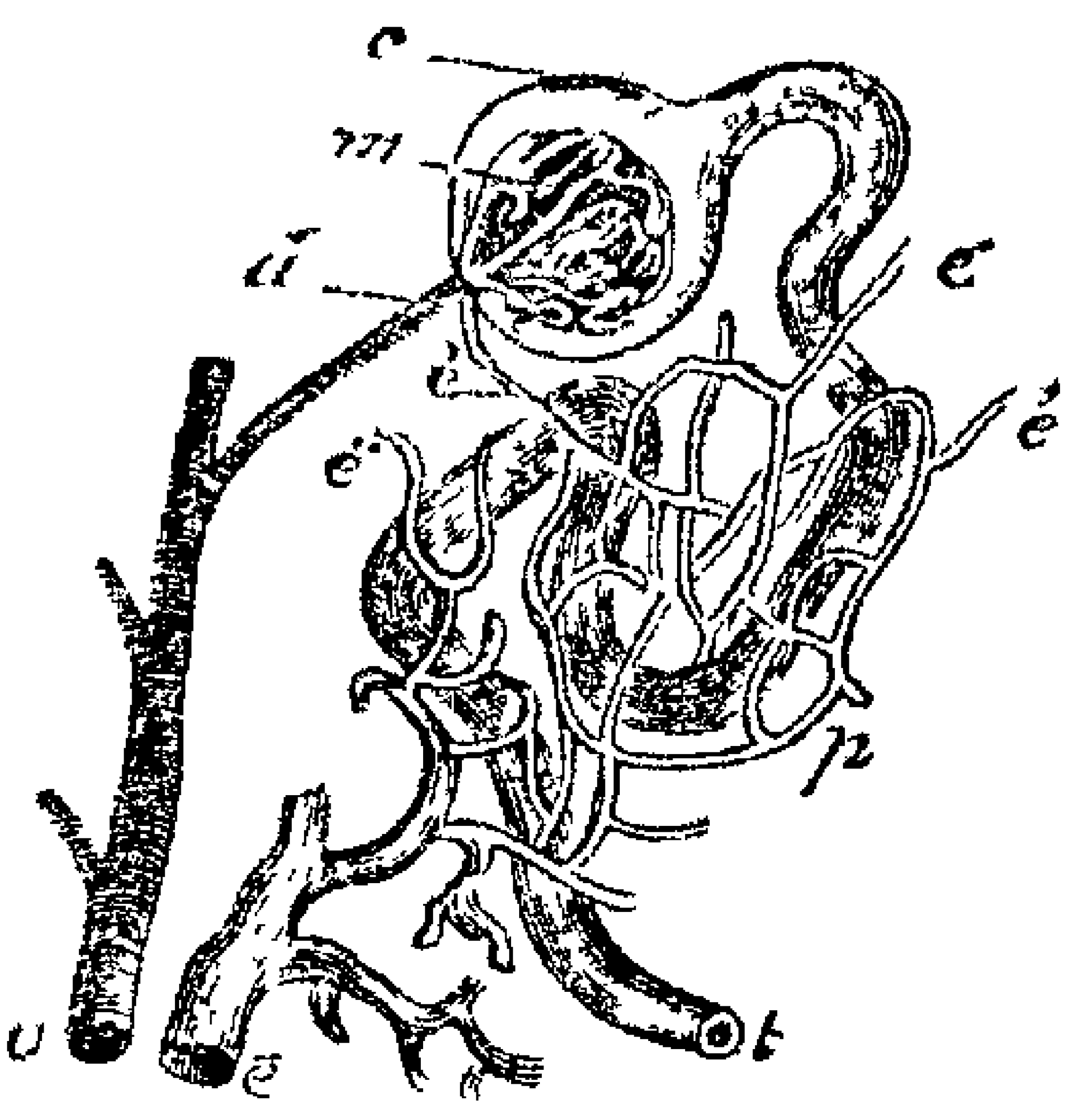


*Fig.* 16.—Diagram showing the relation of the Malpighian body to the urinferous tubes and the blood-vessels. (After Bowman, by the author's permission.) *a*, Artery, which divides into *m*, the glomerulus; *c*, the Malpighian capsule, continuous with *t*, the tubule; *e*, the vein issuing from *m*, the bunch of capillaries in the capsule, and subdividing to form the network around the tubule, and again joining into a branch of the renal vein, *é*.

This venous capillary network at last gathers together into small veins, which unite with one another to make the *renal vein*, through which the blood returns to the inferior vena cava, and so to the heart. The blood in the renal vein is the purest in the body, since it goes into the kidney straight from the aorta and thence is very free from carbonaceous waste, and in the kidney itself the nitrogenous waste also has been removed.

*The Skin* is an excretory organ, and one over the health of which our habits have great influence.

We all know how thin the covering of our bodies

is; but we must not thence jump to the conclusion that there is not much to be learnt about it. It may, indeed, be divided into two skins, and each of these again has two layers. If we pinch up a fold of our skin, we get all the four layers; but when we have a blister raised, the outer skin is separated from the under one. When this division is made, we find that the outer skin is hard, and does not feel pain when it is cut, any more than the hair and nails do; but the under skin is moist, and extremely sensitive. The hard outside skin, which we see when we look at ourselves, is called the scarf-skin, or *epidermis;* the sensitive layer just beneath is named the true skin, or *dermis.*

Each of these, as already mentioned, is composed of two layers. Fig. 17 shows these very well. It can there be seen that the epidermis is divided into the *horny* and *mucous* layers, and the dermis into the *papillary* and *reticular* layers. It will be seen, also, that the four layers are quite closely applied to each other, without the smallest space between them, although they are nevertheless quite distinct from one another in appearance.

The *epidermis,* or scarf-skin, is formed of extremely small cells or bladders. Those of the outer layer are very hard and horny, and are so flat that they may be compared to the scales of fish; this arises from their being always exposed to the air, and from the continual friction against clothing and other external things which they have to encounter. That horny layer of the epidermis is constantly rubbing off, and falling away; but in a state of health the scales are broken up to such a fine dust that we do not notice the fact. The office of the outer scarf-skin is to protect the tender parts underneath, to prevent dirt from getting to them, and to lessen the force of any shock to the nerves. How necessary it is, any one who has ever blistered his hands will know from experience. If we strike gently against any sub-

stance while our hands are properly protected by the horny layer, we have merely the sense of touch; but when any accident has removed that layer the slightest contact gives acute pain, and touch is entirely lost. The epidermis, also, to a great extent, prevents the skin from

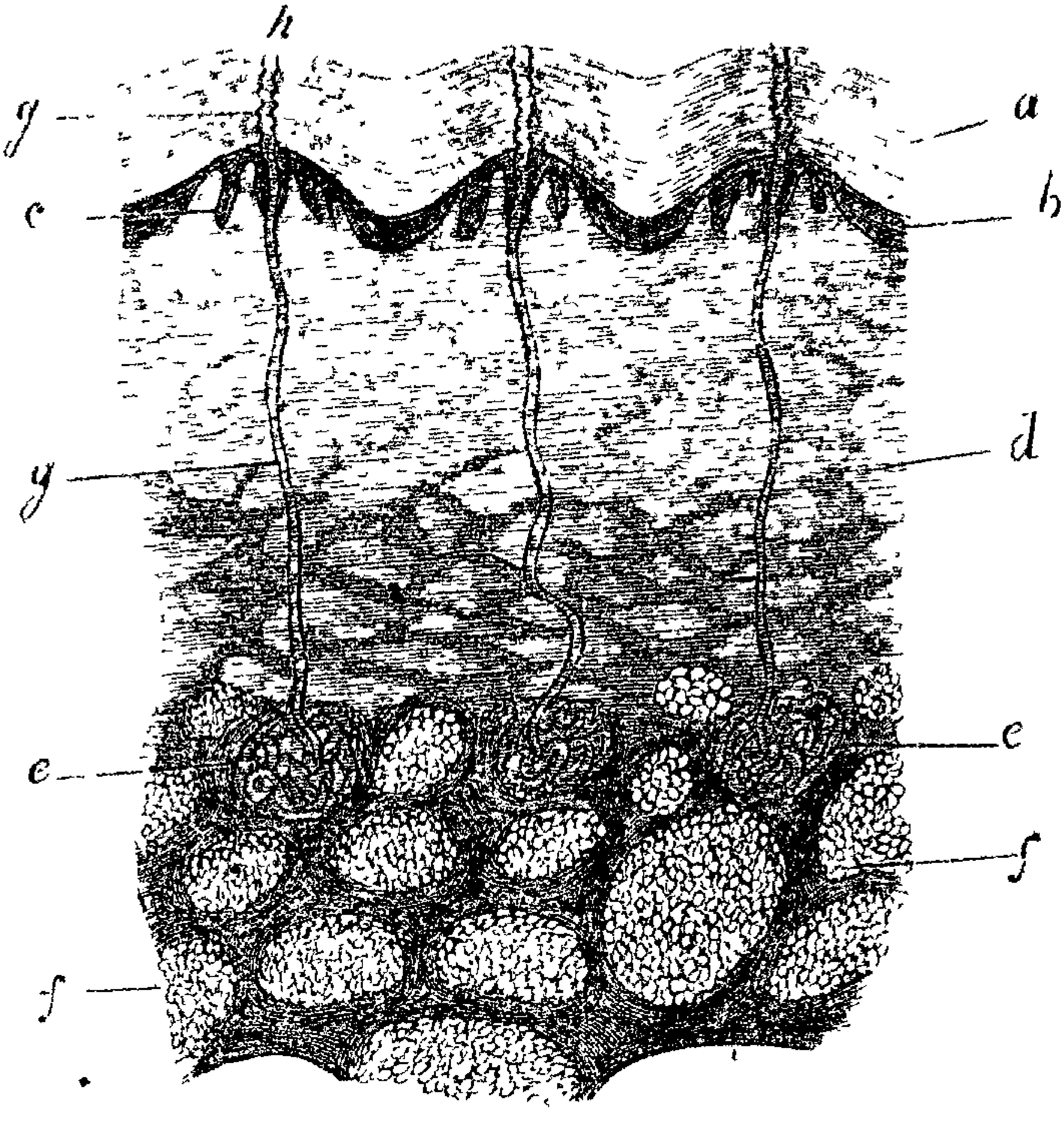


*Fig.* 17.

Section of the skin, showing the sweat glands on the epidermis; *b*, its mucous layer, or *rete* Malpighi; *c*, the papillary layer of the true skin; *d*, the dermis, or *cutis vera*; *e*, the coiled end of a sweat-gland; *g*, its duct; *h*, its opening on the surface of the skin; *f*, fat cells.

absorbing any poisons. Lead, mercury, and other injurious substances, will not enter the blood and affect the constitution unless they are actually rubbed through the scarf-skin; but if there is a scratch or sore, so that the true skin is exposed, the poisons will be drawn into the blood with great rapidity. Workers in lead, looking-

glass silverers, and phosphorus match-makers, ought, therefore, to take great care to cover the smallest scratch upon their hands with wash-leather. And any ointment or lotion for the head or face which may contain mercury, should be scrupulously kept away from parts where the epidermis is rubbed up.

The mucous layer of the scarf-skin, the *rete mucosum*, is composed of cells of the same kind as those of the outer layer, but they differ from the hard external scales by being much softer and plumper. They have only just been made out of the blood, and have not yet been exposed to any pressure or friction. They exist, however, simply to supply the place of the cells which are continually rubbing off the outside of the body. As the cells of the mucous layer are pushed nearer and nearer to the surface by the growth of new ones beneath, they come to more and more exactly resemble the cells of the horny layer; and by the time they reach the top, and are required to be hard and scaly, they have become so, and then form the outer layer. This is how the skin which is unceasingly wearing away is replaced.

The colouring matter of the skin, in the form of minute pigment granules, lies in the rete mucosum.

The top layer of the true skin runs up into and is imbedded in the epidermis. It is called the *papillary* layer, and is formed by small elevations shaped like a sugar-loaf. These little mounds are made of the elastic fibrous tissue which also forms the layer immediately beneath them. Each of them contains one or more capillaries, and also the terminal fibre of a nerve. When an impulse from without reaches those nerve-mounds through the epidermis, we have the sense of touch. The more numerous the papillæ are in any part, the more delicate the sense of touch will be found to be.

The under layer of the dermis is called the *reticular* layer. The word reticular is derived from the Latin for

"a net;" and the term is applied to this part of the true skin, because it is composed of bundles of strong fibres interlacing like a net, in place of the cells of which the scarf-skin is made. The dermis rests upon and blends with a layer of fat, which is stored up, as shown in the engraving, in little bags. And in the dermis are found the glands which give the skin a right to the title of an excreting organ.

There are two kinds of glands in the skin—the *oil-glands* and the *sweat-glands*. The last-named are incomparably the more important.

The oil-glands secrete a small quantity of a natural grease, the purpose of which is to keep the skin supple and elastic, so that it may stretch, as there is evident necessity it should do, at the joints. For this reason they are found most numerously around the joints.

But the sweat-glands do the work of excretion, and therefore are far more important than the oil-glands.

The position in the skin and the structure of the sweat-gland are shown in Fig. 17. It consists of a hollow coil of very thin secreting membrane, placed in the midst of a bunch of capillaries. A slightly corkscrew tube runs up from the coiled gland to the surface of the epidermis, where it ends in an open mouth. By the aid of a not very powerful lens the sweat-pores may be examined on oneself. They are especially numerous on the palm of the hand, in which situation there are no less than three thousand openings on every square inch of the skin. In the whole body there are more than three million sweat-glands, each having its own pore on the epidermis. Mr. Erasmus Wilson calculates the number to be even greater than this; and as, on an average, each gland, when the coil is untwisted, measures a quarter of an inch in length, he reckons that there are, in a full-grown person, no less than *twenty-eight miles* of tubing, engaged in the work of separating from the

blood and casting out on the surface of the body waste matters for which the system has no further use. It might be judged, without any more being said about it, that it must be of the highest importance to keep the outlets of this vast quantity of tubing from being blocked up by dirt; but the full importance of frequently cleansing the skin of the whole body can only be properly realised by considering the work of the sweat-glands as part of the excretory system.

Each one of the three great organs of excretion is constantly at work. When we do not notice that we are perspiring at all, those millions of sweat-glands are really throwing off, in the form of invisible vapour, more than an ounce of fluid every hour, more than a pint in the course of a day. Of every sixteen ounces thus passed out of the body, one ounce is made up of solids (including a little urea), and carbonic acid gas. These matters are nothing less than poison to us. If they are not properly removed from the blood, they will inevitably cause disease, and may cause death.

Now, consider the condition of a person who rarely washes the whole of his body, contenting himself with cleansing only those parts which can be seen. Dr. Mapother, of Dublin, says that this is the condition of many of the poor afflicted with bad skin diseases. The perspiration dries on the body, and holds with it the cast-off scales of epidermis, and the dust and dirt which come against the skin from without. All these matted together form a complete crust over the pores of the sweat-glands. Of course the mouths of the tubes are nearly blocked up, and the action of these most important little organs is seriously impeded.

The result is that extra labour is thrown upon the lungs and the kidneys. The former have to get rid of carbonic acid, and the latter of urea and water, which the skin would have passed off if it had been

kept in a clean and healthy condition. The kidneys chiefly are overburdened. They make every effort to do the additional work that is thrown upon them; but sooner or later they fail under the burthen, and become diseased. Kidney complaints are the result of neglect of bathing to an extent that is quite unsuspected by the people who suffer from them.

But even worse than this may be feared. There is a limit to the power of substitution of action between the skin and the kidneys. If a rabbit be varnished all over, so that the action of its skin is completely stopped, it will die within two hours with every symptom of being poisoned. A similar experiment was once accidentally made upon a human being. When Pope Leo the Tenth ascended the papal throne, a child was prepared to represent in his procession the Golden Age which was supposed to be dawning, by being varnished all over, and covered with gold-leaf, and this poor child died in six hours. Now, whenever the *complete* obstruction of any function causes death, it is quite clear that its *partial* obstruction must do mischief to the vital powers, only less in extent as the evil is less. Therefore, when the work of the sweat-glands is rendered difficult by their being clogged with dirt, not only is the labour of the kidneys greatly increased, but the poisonous matters which the skin should remove are *left in the blood*, and general bad health inevitably follows.

After this explanation it cannot be necessary to add, in so many words, the frequent use of the full bath is necessary to health.

A cold bath every morning is a most valuable and perfect tonic; there is no better strengthening medicine. Not only does it keep the skin in a healthy condition, but it also aids the circulation, and gives tone to the nerves. A plunge-bath—getting all at once into a tub large enough to take in the whole body; a pouring-

bath—standing in a tub, and having a few cans of cold water poured over the head; or even a simple rubbing with a large wet towel—will be found of great value, restoring a weakly person to health, and maintaining the vigour of a healthy one. But whichever form of bath may be adopted, the application of the cold water should always be followed by a brisk and vigorous rubbing with a dry towel until a warm glow is felt. The cold constringes the coats of the capillaries, and drives the blood to the internal organs; the thorough rubbing dry brings the blood back to the surface again. This is what is termed the "reaction," and unless it is secured the bath does more harm than good. A chill remaining after a cold bath, or coming on about an hour later, shows that the reaction has not been perfect. When this is the case the person should stay in the bath for the shortest possible time, just getting in and out again, and should rub the skin with flesh-gloves for several minutes. A cold bath should not be taken within two hours after a meal.

For cleanliness a warm bath and soap must be used occasionally, even by those who take regular cold baths. Everybody knows that warm water removes grease when cold water will not do so; and the secretion of the oil-glands makes our skin greasy. Soap dissolves the outer crust of the epidermis. The scarf-skin is not only as hard as horn, but it has really the same chemical composition as horn. Horn is soluble in alkalies. When it is put into such substances as strong soda-lye it will dissolve. Soap is an alkali, though a very weak one. It follows that when we wash ourselves with soap the outer crust of the epidermis is dissolved, and comes away together with all dirt from the surface of the skin.

Those who desire to keep the skin in perfect health must, therefore, take frequent and regular cold baths, with occasional washings with soap and warm water for complete cleanliness.

Eruptions upon the skin are among the signs of infectious diseases, and show how powerful an agent the skin is in cleansing the system. Infectious diseases are those which can be conveyed from one person to another without the healthy touching the sick. Naming them in the order of their infectiousness they are:—Smallpox, scarlet-fever, typhus, measles, hooping-cough, diphtheria, and probably typhoid fever and cholera. In nearly all of these there are spots upon the skin; but they are blood diseases, and the eruption is merely Nature's endeavour to throw the poison out of the body.

Isolation of any person suffering from such a disease is an absolute necessity. The patient must have a room to himself, and nothing should be permitted to go out of that room—neither clothing, nor bedding, nor carpets —until it has been disinfected with carbolic acid, or some other chemical preparation with similar powers. Doubtless one of the ways in which infection is carried from place to place upon clothing, or floats through the air for long distances, is by the falling off of the epidermis, which, as already said, is continually happening. After scarlet fever, the skin of the whole body generally peels off in flakes, and it is not safe for the sufferer to mix with healthy persons until this process is quite completed.

Clothing is worn to protect the skin from sudden changes of temperature, and to prevent it from parting too rapidly with its heat. Flannel is the best material for garments which are next the skin, since it both retains heat (in other words, is a bad conductor) and absorbs perspiration. For a variable climate, such as that of Great Britain during the spring and autumn, it is most valuable. Linen is the coldest and most objectionable of fabrics to place against the skin. Calicoes occupy an intermediate position between linen and flannel, as regards the readiness with which they allow

heat to pass through them; and cotton garments are perhaps best for wearing next the skin in the height of summer in a temperate climate, because they wash so much better than flannels, and are therefore more likely to be changed often.

All kinds of powders, paints, and washes for the face are injurious to the skin. In the last century there lived two exceedingly beautiful young ladies named Gunning. They were so lovely that they were mobbed, when they walked in Hyde Park, by their admirers. One of these beautiful girls died early in life from a cancerous disease of the face, caused by her painting her cheeks when late hours and hot ball-rooms had removed the natural bloom which she brought from her native Irish hills and dales. This is a high price to pay for a little fleeting admiration.

# CHAPTER X.

## THE EYE AND ITS HEALTH.

THE structure of the eye, adapted as its details are to produce all the wonders of the sense of sight—to enable us to see equally well the point of a needle held close to us, and a landscape of miles in extent, to distinguish colours and shapes, and to form accurate judgments of distances and positions—is both somewhat complicated and very beautiful.

The description which I am about to give of it will be much better understood if you will procure and examine some bullocks' eyes. Five or six eyes should be obtained, so that the organ may be examined from several points of view.

Fig. 18 represents a slice, cut right down through the centre, of an eyeball which has been hardened in methylated spirit. Look well at it, so as to become perfectly familiar with the arrangement of the parts. The aqueous humour and the vitreous humour are *fluids*, filling the cavities in which they are placed: the sclerotic and cornea, which together form the outermost coat of the eyeball; the choroid, the ciliary processes, and the iris, which together make the second coat of the eye; and the retina, which lines the inside of the globe, are all *membranes*, each having its own peculiarities of structure: and the lens is a transparent crystal-like *firm* body, separating the aqueous and vitreous humours.

You will notice that the eyeball is not a perfectly

round globe, but has a projection in front, which is like a piece cut off a smaller globe and fixed upon the front of the larger one. If it were not for this projecting piece on the front, the eyeball would be a globe of just an inch in diameter; but the curving out of the front makes it an inch and a sixth.

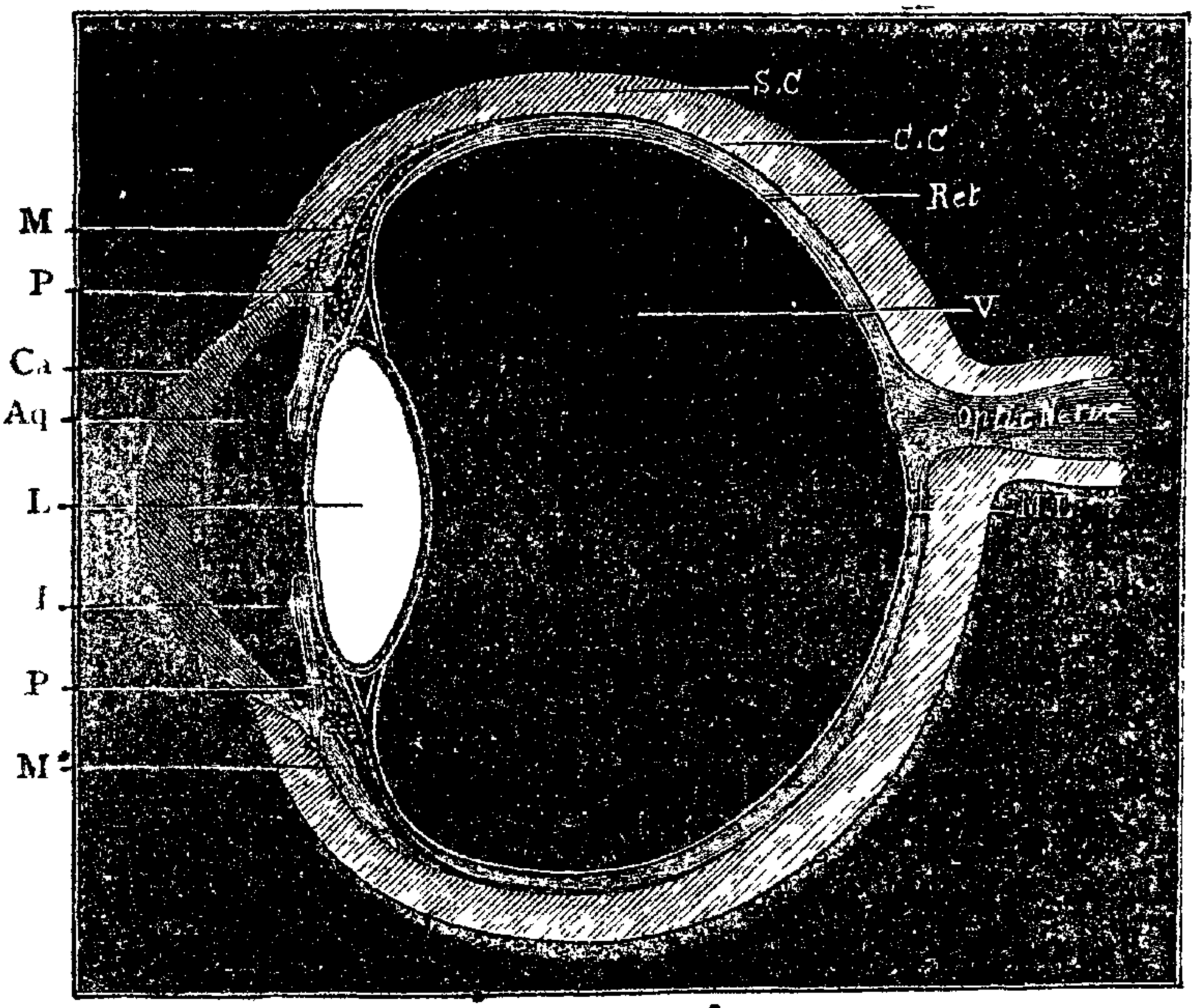


Fig. 18.—SECTION THROUGH THE LEFT EYE.

*S.C.*, Sclerotic coat; *C.C.*, choroid coat; *Ret.*, retina; *V.*, cavity filled by the vitreous humour; *M.M.*, ciliary muscle; *P.P.*, ciliary processes cut through; *I.*, the iris; *L.*, the crystalline lens; *Aq.*, the cavity filled by the aqueous humour; *Ca.*, cornea; *M.L.*, macula lutea, or yellow spot.

The outermost coat of the eye is a very thick strong membrane. All round the back and the sides of the ball it is opaque; that is, we could not see through it. But just that little piece in the front which bulges out, and which we call the *white* of our eyes, is transparent. All that part of this outermost coat which is dense and opaque is called the *sclerotic;* the transparent, glistening

piece in front is the *cornea*. Note where the cornea and the sclerotic join on to one another; just there are several structures which must be described in detail presently.

The second coat of the eyeball, lining the sclerotic, and ending just where that membrane does, is called the *choroid*. It is a membrane with a great number of blood-vessels in it, and is lined inside with a layer of black pigment cells. The choroid runs right round the whole of the back three-fourths of the eyeball; but it ends just beside the crystalline lens (see Fig. 18) in a very peculiar manner. It wrinkles up into a series of ridges and depressions, something like a goffered frill on the bottom of a lady's starched white petticoat. These ridges are called the *ciliary processes* of the choroid coat. They are shown in Fig. 19, or you can see them by cutting a bullock's eye round the middle of the ball (transversely), and looking at the front half from behind. The ciliary processes appear something like the rays which you may have seen painted on a sign-board around the face of "The Rising Sun."

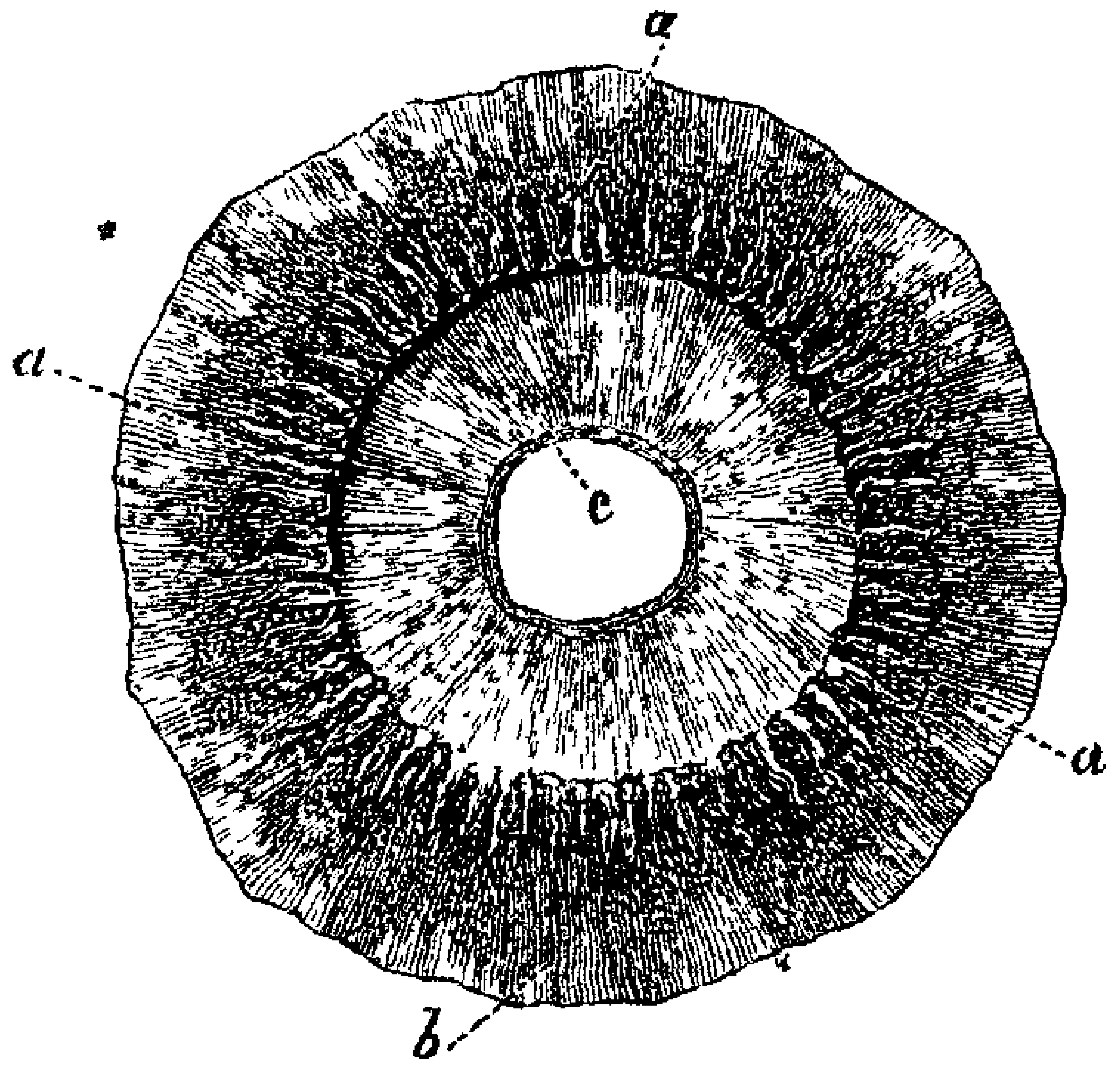


*Fig.* 19.—Ciliary Processes of the Choroid Coat, seen from behind.

*a*, Ciliary processes, about sixty in number in this specimen; *b*, front part of the choroid coat; *c*, circular and radiating muscular fibres of the iris—the letter is placed in the pupil.

The top fibres of the ciliary processes pass on into the *iris*, which thus forms the foremost part of the second coat of the eye. The iris is the coloured part of the

eye; if we talked in every-day life with that precision which is termed pedantry, we should never say "What colour are his eyes?" but "What is the colour of the anterior pigment cells of his iris?" The back of the iris is always covered with very dark-coloured cells, whatever may be the tint of its anterior surface. It was just said that the ciliary processes pass on to and join with the iris; in like manner, the dark pigment cells on the posterior surface of the iris are continuous with those of the choroid coat and its ciliary processes.

The substance of the iris consists essentially of muscular fibres. It has a round hole in its centre which we call the "pupil." Some of the muscular fibres radiate upwards from the pupil; others form a ring around it. The result of this arrangement is that the size of the pupil varies. The contraction of the radiate fibres increases the size of the hole, while the action of the circular fibres diminishes it. Now, the muscular fibres in the iris are involuntary ones, as those of the heart were described to be in Chapter III.; and the special stimulus which causes the contraction of the fibres in the eye is *light*. If you get some one to first stand with his eyes looking right at a window, and then to turn his back to the light, you can see that the pupil is four times as large in the last as it was in the first position. If a glare of sunshine passed right into our eyes, we should be blinded by it. But such a glare causes the contraction of the circular fibres of the iris, and that contraction diminishes the size of the pupil; and since light cannot pass through the pigment cells, but only through the hole, the quantity of light which enters the eye is thus carefully regulated without our consciousness or will being required to act in the matter.

Between the cornea and the iris is a thin watery fluid —the *aqueous humour*. Behind, the iris rests upon the crystalline lens.

The *lens* is a beautiful transparent body, clear as

crystal, and convex—that is, bowed outwards—both before and behind. If a fresh eye is cut round transversely, between the cornea and the back of the sclerotic, a little squeeze will bring out the jelly-like vitreous humour with the lens attached to the front of it. The crystalline lens is inclosed in a bag of elastic membrane, called its capsule; and is held in position by another membrane, the *suspensory ligament of the lens*, which runs from the edge of the capsule to the edge of the choroid, all round the lens, and which has folds that exactly fit into the depressions between the ridges of the ciliary processes; thus the lens, like the iris, is fastened to the choroid coat. Just at the same place, around the iris, is a circular band of muscular fibres, called the *ciliary muscle*. This band also runs round the eyeball, immediately behind the iris, and extends *from* the point where the cornea and sclerotic join into each other *to* the choroid coat, passing over and being attached to the ciliary processes (Fig. 18). You can see that when this muscle contracts it will pull the choroid coat forwards toward the point of junction of the cornea and sclerotic. Try to understand all this, because by its aid you can comprehend presently how the eye may be adjusted to far or near objects.

The *vitreous humour* fills all that large cavity which is behind the lens. It is a watery transparent fluid, which supports and keeps stretched out the internal membrane lining the globe, the only part of the eye remaining to be described, and the most important structure of the whole—the *retina*.

When the vitreous and the lens together are pressed out of a fresh eye, a very delicate white membrane will be found to collapse in the back half of the cut globe, and to remain attached to the choroid coat just by a few threads, nearly in the centre of the half of the ball. The membrane is the *retina*, and the place where it remains fastened is where the nerve of sight enters from

the brain and spreads out upon the surface of the retina.

It requires a little exercise of the imagination to realise that this exceedingly fine membrane which we see is composed of three distinct layers, and is very complex in detail. Yet such is the fact, and these three layers are bound together by what are called the *fibres of Müller*, which perforate them and unite them (see Fig. 20). The outer layer of the retina (that is, the one nearest to the choroid and farthest from the vitreous) is called *the layer of rods and cones.* It consists of a vast number of rods laid along side by side, with cones—little bodies shaped like sugar-loaves—mixed in with the rods. They are both laid perpendicularly, so that one end of each rod or cone points toward the choroid, and the other toward the vitreous humour. This layer forms about one quarter of the thickness of the retina. The second layer is composed of fine fibres and cells. The third layer, which is nearest to the vitreous humour, is made up of nerve-cells and nerve fibres. The fibres are made by the spreading out of the *optic nerve.* You can see (Fig. 18) where this nerve

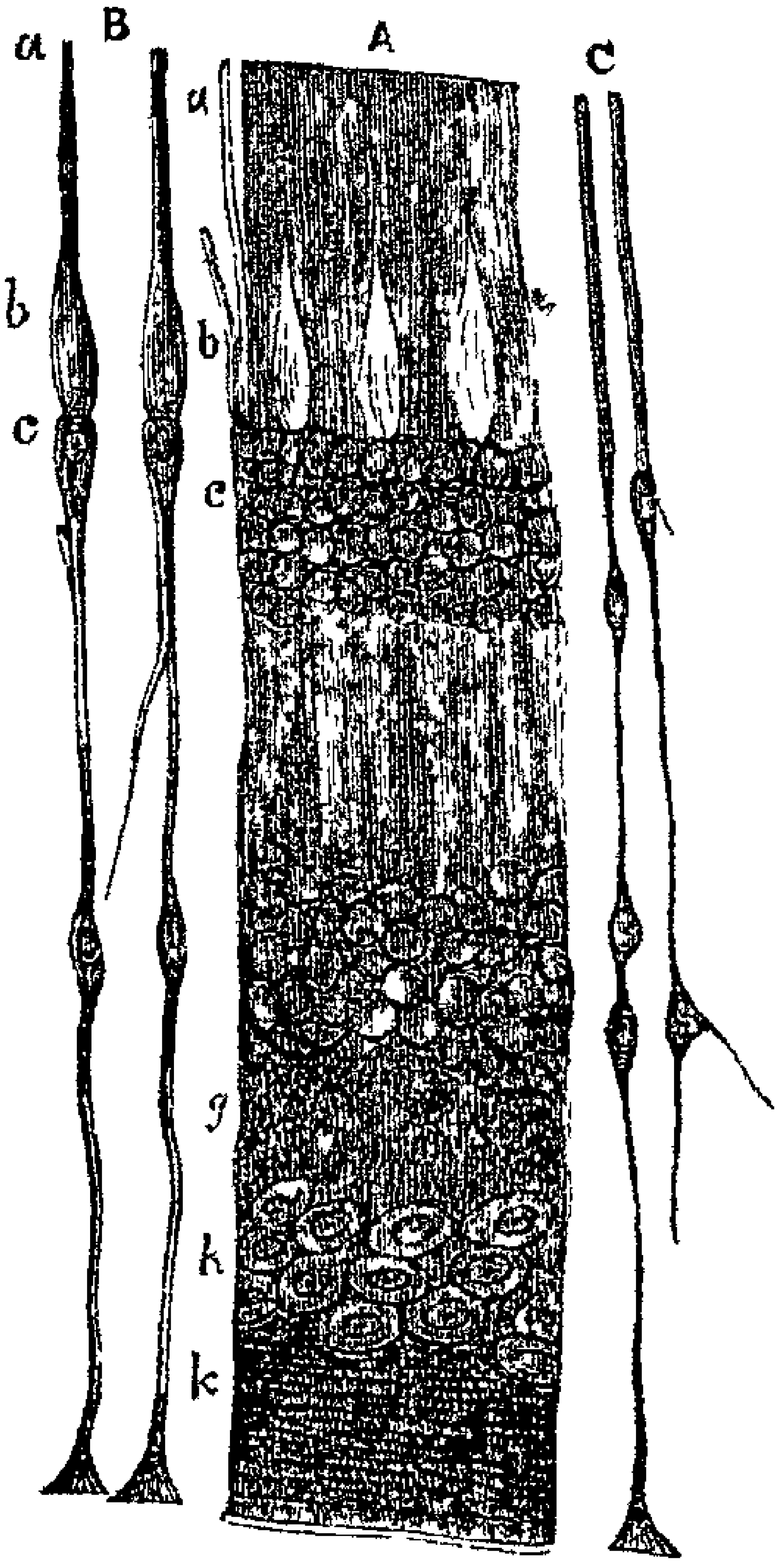


*Fig.* 20.—PORTION OF THE RETINA (magnified 250 times).

A, section of the retina, showing the complete structure; *a* to *b*, the layer of rods and cones; *c* to *g*, the granular layer; *h*, nerve-cells; *k*, nerve-fibres, produced by the spreading out of the optic nerve. B, two cones, represented separately, in connection with the fibres of Müller and granules. E, two rods, similarly represented.

enters the eye. It passes through the sclerotic and choroid coats, and then spreads out so as to form the innermost layer of the retina. The nerve begins right back in the brain; so that it is really a cord running between the eye and the brain.

Where the optic nerve enters from the brain, there are none of those peculiar little bodies, the rods and cones; and by knowledge of this fact we discover, what is very remarkable, that it is the rods and cones which see, and *not* the fibres of the optic nerve. The point at which the nerve enters and spreads out, and where, of course, its fibres are most thickly distributed, is absolutely blind; so that the point of entrance of the optic nerve is actually called the "blind spot." But there is a place in the retina where there are no fibres of the optic nerve to be discovered, but where the cones become very numerous; and at that point vision is stronger than at any other.

This last-mentioned point is called the *yellow spot*, and is situated in the very centre of the back of the eye, so that the image of any object which we are looking "straight at" will fall directly upon that point (Fig. 18). Microscopic examination of the yellow spot shows that the layer of rods and cones becomes much wider at this place, and that the proportion of cones to rods is increased, while the other layers of the retina become so much thinner as to be nearly absent. In fact, the yellow spot is composed almost entirely of cones.

Now, to prove to you that the entrance of the optic nerve *is* the blind spot, and that the yellow spot *is* the most sensitive part of the retina. Shut the left eye, and look with the right at the cross on the page, holding the book about ten inches from the tip of your nose. You will be able to see the dot, as well as the

cross at which you are directly looking. Now, keeping

the eye fixed steadily upon the cross, bring the book slowly up toward your face. Presently you will come to a point at which the dot becomes quite invisible, and only the cross can be seen. Continue to draw the book nearer to you, and, in another moment, behold! you can see both cross and dot once more.

What is the meaning of this? Here it is. The image of the object at which we look straight and steadily necessarily falls upon the yellow spot, exactly in the middle of the back of the eyeball. Thus, the figure of the cross rested the whole time upon that spot. The image of the dot, in the first position in which you held the book, rested between the yellow spot and the entrance of the optic nerve, which is toward the nose, not in the exact centre of the globe. When the book was drawn nearer, the image of the dot had to move round, so that it came upon the entrance of the nerve; then you could not see it at all. Moving the book yet closer, you passed the figure of the dot round farther, so that it fell between the nose and the entrance of the nerve; then it became visible again. The conclusion which we must draw from this small experiment is that, since every part of the retina can see *but* that which has no cones yet has many fibres of the optic nerve; and since vision is most acute where there are most rods and cones and no nerve-fibres; therefore it must be the rods and cones which actually produce vision and not the fibres of the optic nerve.

But seeing is really the work of the brain. If we could cut the optic nerve without injuring any other part of the eye, we should not be able to see, because no impulse could be carried to the brain.

It appears, therefore, that the layer of rods and cones receives the impulse of light, and has the power of making that impulse act upon the fibres of the optic nerve, which, when acted upon, carry the impulse on to the brain; and thus the sense of sight is obtained.

"The impulse of light;" what is that?

Light is believed to be produced by the movements of an exceedingly thin fluid, called *ether*, which surrounds us in every place. Ether is very much thinner than air, and its vibrations can pass through the transparent membranes and humours of the eye, and strike upon the retina. When a ray of light falls upon any opaque body, the impulse is *reflected*, or thrown back; and it is these reflected vibrations which form the image of the object upon the retina.

The use of the convexity of the cornea, and the double convexity of the crystalline lens, is to bend the rays of light to a point, or *focus*, that they may strike upon the retina. You cannot quite thoroughly comprehend how they act without studying at length the laws of optics. But you will be able to understand thus much: that to form an image of any object, the rays of light which proceed from a given point of it must correspondingly strike upon a given part of the retina. Thus, if some rays come from a gas-burner near the roof, and other rays proceed from one lower down, it is necessary for vision that the rays from the upper burner should strike on a different part of the retina from that which is affected by the rays of the lower one. To secure this, certain structures (viz. the cornea, lens, and vitreous and aqueous humours) are placed in the eye to bend all rays which proceed from one and the same external point in one and the same direction. By this bending, the different rays are accurately thrown upon the retina at points corresponding to the position of the points from which they radiate in the object.

An ordinary spectacle glass is a doubly convex lens —that is, bowed outwards on both sides, and thicker in the centre than at the edges. It will, therefore, serve to demonstrate that such a lens does so bend rays of light that pass through it as to cause them to converge upon one spot, and arrange them in positions corresponding to the points from which they are emitted.

Fix a sheet of white paper against the wall of a dark room; then take a candle near to the paper, and hold the spectacle-glass between the two. By moving the candle and glass backward and forward, you will find a certain distance at which an image of the flame, upside down, is shown upon the paper. By moving the candle either nearer or farther away, the image upon the paper is made indistinct; there is just the one point from which the candle is clearly reflected, and this is called the *focal distance* of the lens. The more convex—that is, bowed outwards—the lens is, the more acute is the angle to which it bends rays passing through it, and, consequently, the nearer to it is its focus, the shorter its focal distance. Thus, therefore, when we look at things which are quite close to us, we want a more convex lens to bring their reflected rays to a point on the retina than we need when the object is far away from us.

To adjust the eye to distances is the work of the crystalline lens. The convexity of the cornea is unchangeable; but that of the front of the lens becomes greater or less, according to the distance from the retina of the object of vision. The exact method by which this adjustment is produced has long been a disputed question; but the following is the now generally received explanation:—The lens is always kept in a state of tension, and so somewhat flattened, by its elastic capsule, and by its suspensory ligament. This ligament, you remember, is attached to the ciliary processes. Now, by the contraction of the ciliary muscle (as we saw before,

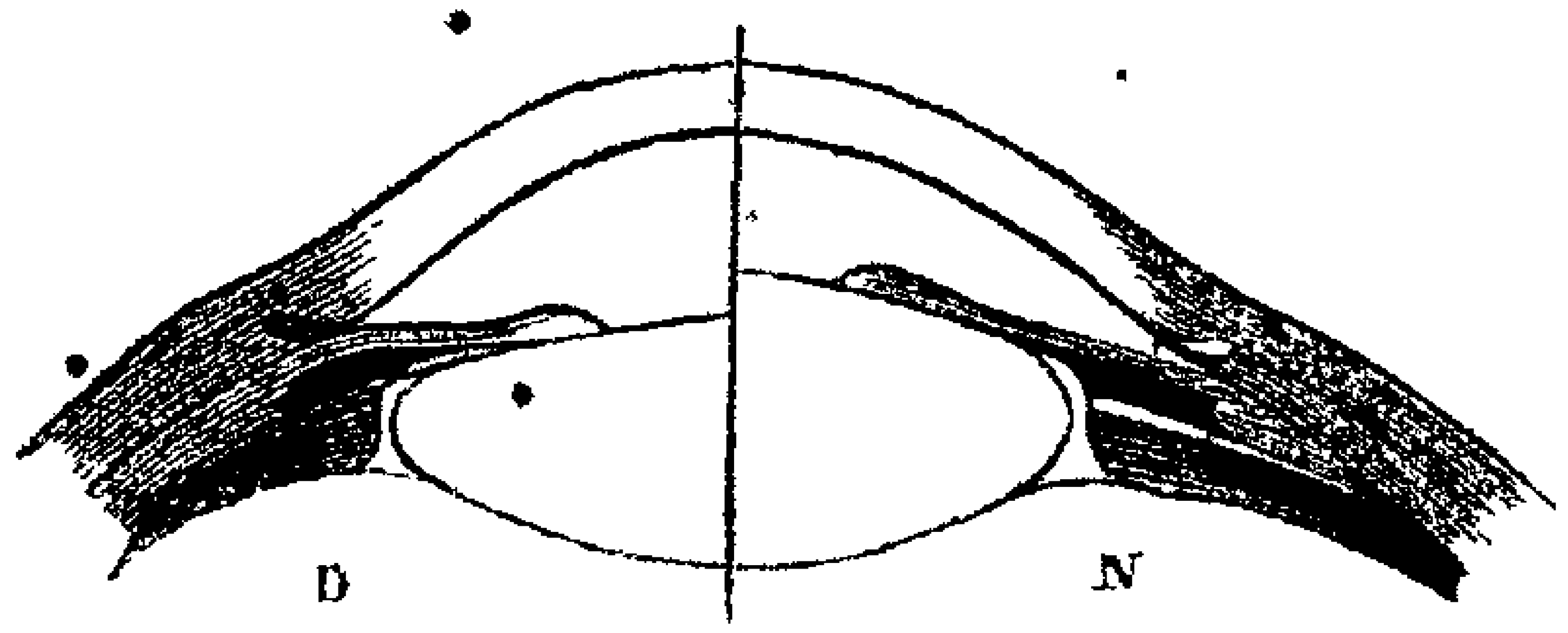

*Fig.* 21 illustrates the alteration in the convexity of the lens when adjusted; D, to distant objects; N, to near objects.

p. 115), the choroid and ciliary processes must be pulled forward all together. Such a change must relax the tension of the suspensory ligament, and therefore permit the lens to assume a more convex shape. That is what is held to occur when we bring our eyes to bear upon near objects; and the sense of effort which we feel is caused by the contraction of the ciliary muscle. In proportion as that contraction is diminished, the elasticity of the suspensory ligament pulls the lens flatter, and so adjustment to far objects is obtained.

You saw that the image of the candle was thrown by the lens upon the paper *upside down*. All images are necessarily formed upon the retina in like manner; but we reverse them by an act of judgment in the brain, having insensibly found out by experience that a point which is reflected at the lower part of the retina is, as a matter of fact, as touch shows us, higher than the one apparently above it.

Near-sighted people have too long eyes (from before backwards), or the cornea too convex, or else are not able to flatten the lens sufficiently. The consequence is that objects are brought to a point too soon in their eyes, and the image falls in front of, instead of upon the retina, unless it is held very close to them; this defect may be partly remedied by wearing *concave* glasses.

Others suffer in the opposite way to this, being unable to discern clearly objects which are close to them; the cornea or the lens is flatter than it should be, and hence the focal distance would be a point *behind* the retina while the object was at the ordinary distance from the eye. This is commonly the defect of sight from which elderly people suffer. *Convex* glasses must be worn by persons whose eyes are in this condition.

It is not wise for people who require spectacles to go to a shop and choose a pair for themselves. Surgeons who give special attention to the eyes (opthalmologists)

have always a set of types and glasses for ascertaining the exact degree of convexity or concavity required in each case; and if this is not properly found, the spectacles bought are very likely to be either too weak or too strong, in either of which cases they will injure the sight. Glasses should not be so strong as to magnify an object, but only to render it clear and distinct when held at an ordinary distance from the eye.

Reading when travelling, or under a flickering light, is very bad for the eyes, because the focal distance is changed every few seconds, and the lens has to perpetually alter its adjustment in consequence. The retina, also, is fatigued by the unsteadiness of the impression.

Light ought not to be allowed to fall directly upon the eyes when we are reading or working, but we should be so seated at the desk or table that the light falls over the left shoulder. If we have the light coming over the right shoulder, the hand throws a shadow which obscures the work.

Dr. Reynolds says,—"Among habits which exert an unfavourable effect upon the eyes, the use of tobacco ought not to be passed over unnoticed. There can be no doubt that this powerful narcotic is highly detrimental." Mr. Critchett, and other great London oculists, have recently borne testimony to the frequency with which partial blindness is induced by the excessive use of tobacco, especially among very young men.

When the eyes ache and smart after working a short time, they should be rested for a few minutes as often as possible. Cold water is almost the only application which should be made to the eyes without medical orders. When there is a feeling as of sand under the lids, and when small congested blood-vessels are visible on the cornea, a very little pinch of alum in a tumbler of cold water makes a simple and good eye-water.

Here is an anecdote from an old writer, which may give a needed warning to young folks who are fond of fun.

"I was once called to a man who had enjoyed a remarkable vision, and who, but a short time previously, had suddenly gone stone blind. He was in the company of some familiar friends, when a stranger suddenly came behind him, and covered both his eyes with his hands. Now he was to tell who was behind him. Whether he knew or not I cannot say; but without speaking a word, he endeavoured to free himself from the pressure. But the more he endeavoured the more firmly did the other press with his hands; until, when they were removed, he found, on opening his eyes, that the sight was for ever gone."

The *appendages of the eye* are the *lachrymal gland*, situate at the outer corner of the orbit, and secreting the tears, which serve to keep the eye moist, and which, when not excessive in quantity, pass down the *lachrymal duct* into the nose; and the *eyelids*, *brows*, and *lashes*, which protect the eyeball. A thin membrane, called the *conjunctiva*, covers the inside of the eyelids, and is reflected (*i.e.* bent backwards) over the cornea.

The eye is turned from side to side by the action of six small muscles. Squinting is produced by the excessive strength of one of these muscles, which makes it act against the others with more power than it should do. Thus, when an effort is made to look at any given point, the eyes do not respond exactly to the will, and the image of the object falls in different axes on the retinæ. Squinting is not merely a serious deformity, but also produces weakness and eventual great injury to one or both of the eyes; it should therefore be always attended to. The operation is by no means a formidable one. The vulgar expression "turning the eye" does not convey the truth. All that the surgeon does is to make a small snip through the conjunctiva and divide the tendon of whichever muscle is at fault. This is neither dangerous to the sight nor very painful.

# CHAPTER XI.

## THE EAR, TOUCH, TASTE, AND SMELL.

How often poets and novelists have compared the daintily-shaped and delicately-tinted ear, laid so prettily in relief against the deeper colour of the hair, to a sea-shell hiding under the grasses of an ocean cave. I wonder if they knew that they were borrowing a simile from anatomists? For such is the truth. Science calls that outer ear the *Concha*,[1]—that is, the shell. And indeed the poetical faculties, Imagination and Fancy, have been drawn upon very much for the nomenclature of the organ of hearing. You will see how fanciful and suggestive most of the terms are.

The concha, although it commonly receives the title of *the* ear, is only a small and a comparatively unimportant portion of the organ of hearing. Its purpose is to collect the vibrations of the air which make sound, that they may the more readily pass to the auditory nerve; in fact it is a natural ear-trumpet. The tube leading into the head from the centre of the concha is the *external auditory meatus*, the outer passage of hearing. It is a canal an inch and a quarter in length. The concha and the external meatus are classed together as forming

[1] Many anatomists confine this name to the central depression of the outer ear, and term the entire external cartilage the *pinna* or *auricle*; but others, including Professor Huxley, use it as I have used it above, and its poetical excellence as a name for the whole outer ear is obvious.

the first division of the organ, and make up what is called the *external ear*. The whole organ is divided, for convenience of description, into three parts; and the portions yet remaining to be described are termed respectively the *middle* ear, and the *internal* ear or *labyrinth*.

At the bottom of the outer passage of hearing, there is a membrane stretched tightly across. This is the boundary between the external and the middle ear; it is named the *tympanic membrane*, or membrane of the drum of the ear. The cavity which it covers in is the *tympanum*, or drum. A membrane alone, you know, cannot be a drum; to make one, it must be tightly stretched over a hollow space; but one of the errors of common speech is to call the tympanic membrane itself "the drum of the ear."

The communication between the external and middle ear is quite cut off by the tympanic membrane, through which no fluid or solid can pass; so that if a small insect, or such a thing as a bead, or pea, should happen to get into the ear, there is no fear of its going in very far. More mischief is likely to be done by efforts to extract the substance than by its mere presence in the canal. The best way to remove an insect from the ear is to lay the head upon a pillow, in such a manner that that ear is uppermost which has the intruder in it—thus, if the left ear is the one "taken by assault," the right side of the face must be lain upon—and to quite fill the passage with sweet oil. In all probability, the insect will float to the top very quickly. Even if it should not do this, it will certainly die, and then can be readily removed. In the case of a solid body, if it will not fall out when the ear is turned downwards and the opposite side of the head gently struck, the patient should be taken at once to a surgeon, whose instruments will probably remove the substance with comparative ease. Incautious poking into the ear under such circumstances

is extremely likely to rupture the tympanic membrane, and so to injure the sense for ever.

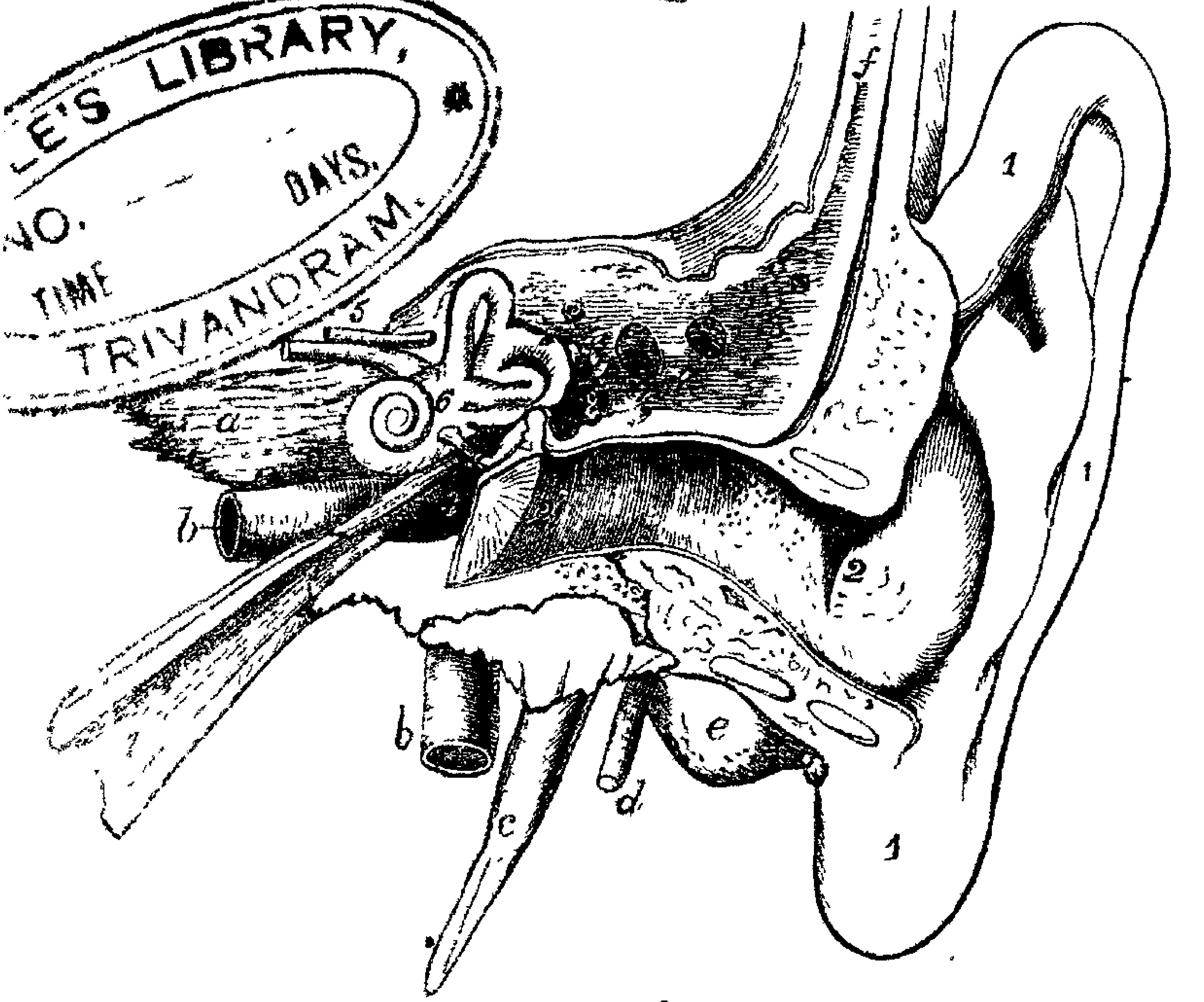


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*Fig.* 22.*

Diagrammatic view from before of the parts composing the organ of hearing of the left side (after Arnold).—The temporal bone of the left side, with the accompanying soft parts, has been detached from the head, and a section has been carried through it transversely, so as to remove the front of the external meatus, half the tympanic membrane, and the upper and front wall of the tympanum and Eustachian tube. The internal meatus has also been opened, and the bony labyrinth exposed by the removal of the surrounding parts of the petrous bone. 1, The concha; 2, external meatus; 2′, membrana tympani; 3, cavity of the tympanum; between 3 and 6, the chain of small bones; 4, Eustachian tube; 5, the facial and the auditory nerves; 6, the internal ear, the figure is placed on the vestibule of the labyrinth above the fenestra ovalis; *b*, internal carotid artery; *d*, facial nerve: *a*, *c*, *e*, *f*, portions of bone.

Air enters the middle ear through the mouth, the *Eustachian tube* running from the back of the throat into the drum (Fig. 22). Above the opening of this tube—

* From Kirkes' *Physiology*.

that is to say, on the opposite side of the tympanic cavity from the membrane of the drum, is a little bony prominence, and two apertures filled in with membrane, like windows filled in with glass; these together make up the back wall of the middle ear, and separate it from the internal ear. The apertures in the bony wall just mentioned are called windows: that one which is above the promontory is the *fenestra ovalis*, and that one which is below it is the *fenestra rotunda*—the oval window and the round window. Both these windows *look into* (so to speak) the internal ear; if you passed a bristle through either of them it would enter that division of the organ.

A little chain, made up of three tiny but distinct bones, joined on to each other, runs across the cavity of the drum from the tympanic membrane to the oval window. All three bones have fanciful names. If you break down the membrane of the drum in a boiled sheep's head by pushing a skewer into the ear, you may be able to shake the ear bones out through the external meatus; if you cannot get them in that way, you may succeed in finding them by opening the hard bone just behind the outer ear of the sheep. Of course, the meat can be taken off the head first. Understand that the bones are each but little larger than a pin's head, so carelessness will assuredly miss them. If you succeed in getting them, you can gum them on a card, and observe how appropriately they are named by their shape.

The first of the three is called the *hammer*—in Latin, the *malleus*. The end of the handle of the hammer is fixed to the tympanic membrane, while its head fits into a depression on the top of the second of the chain of bones. This next one is called the *anvil*, or *incus*; but it might more correctly, says an authority without a poetical mind, be compared to a double tooth. The foot of the anvil is fastened to the third and last of

the chain of bones, which is called the *stirrup*, or *stapes*. This bone exactly resembles the object after which it is named. The upper part of the stirrup is attached to the anvil, while its foot-plate is fastened firmly to the membrane that fills in the oval window. Thus these bones form a bridge across the middle ear, and a means of communication between the tympanic membrane and the oval window.

Now we have reached the most difficult part of the description; for on the other side of the oval and round windows we find the internal ear, and justly has that received the name of the Labyrinth. But it is highly interesting to thread our way through it.

The internal ear consists of a series of channels excavated, as it were, out of one of the bones of the head, and of various membranous structures lying inside the bone, and in part resembling their covering in shape. It consists of three portions: the *semicircular canals*, the *cochlea*, and the *vestibule*, or porch, into which both the first-named parts open.

The bony semicircular canals are three in number. They are more than half, nearly three-quarters circular in shape. Of course, each canal has two ends; and these all open near each other into that central cavity which is called the porch or vestibule, because it is the entrance to the whole labyrinth. Two of the canals, however, join together just before their termination, and thus there are only five openings into the vestibule. The membranous semicircular canals lie inside the bony ones; in the annexed engraving (Fig. 23) one half of the bone is removed to show the soft tube inside. You see that the membranous canals have the same shape as the bone in which they lie; and that they do not "fit tight," being considerably less in diameter than the bony canals. The swellings which are shown at the end of the tubes are called the *ampullæ*.

Within the bony vestibule are two membranous sacs, lying loosely inside the bone, as the membranous canals lie inside the bony ones; only the *bony vestibule* is *one* cavity, while the *membranous vestibule* consists of *two* parts; but the *soft* semicircular canals *exactly correspond*

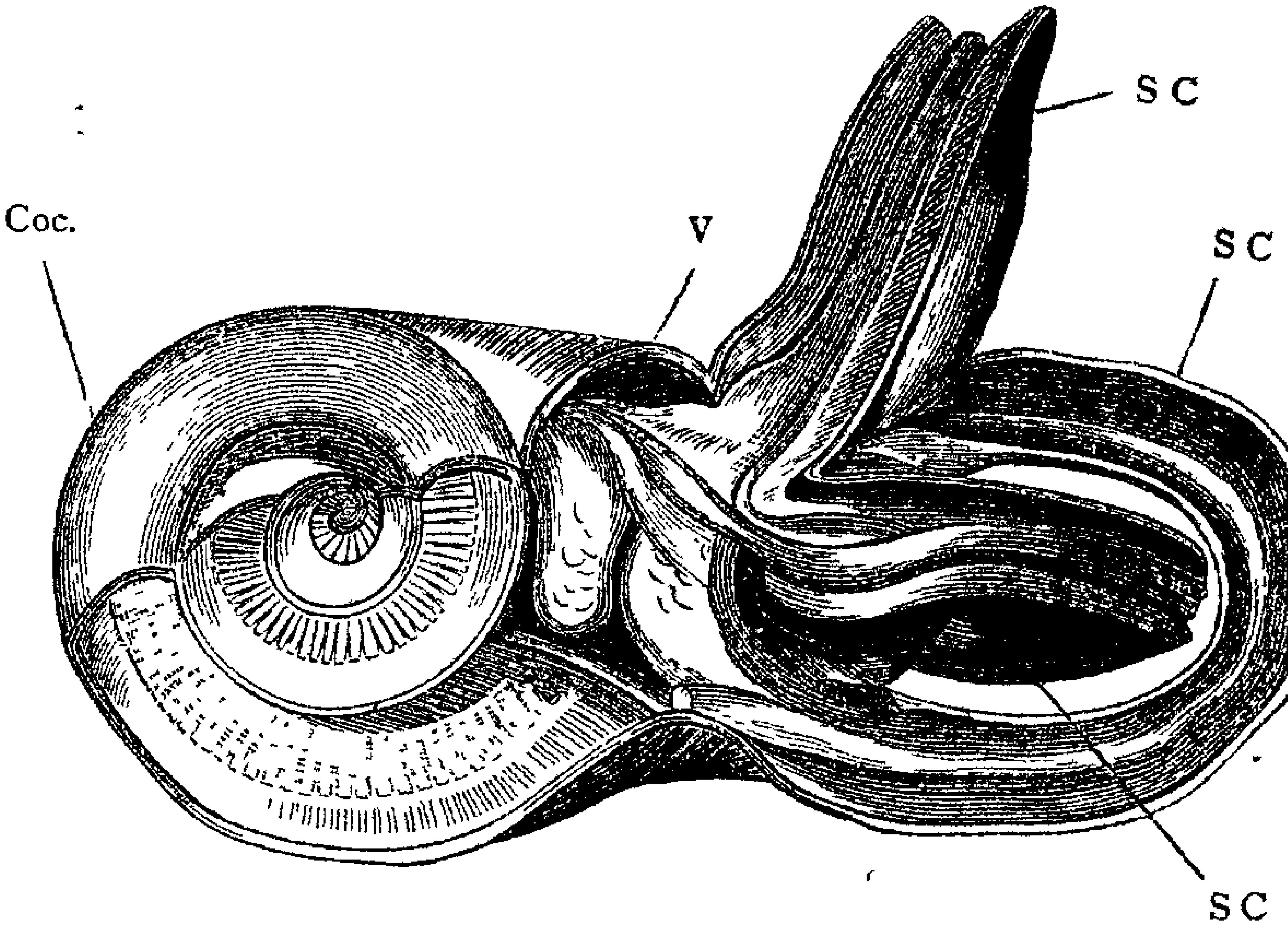


*Fig.* 23.—THE INNER EAR.
Coc., Cochlea; V, vestibule; S C, semicircular canals, laid open.

with the *bony* surrounding ones. The membranous vestibular sac into which the canals open is called the *utricle*; the other sac, which communicates with the cochlea, is called the *saccule*.

The membranous canals and vestibular sacs are hollow, and are full of a watery fluid named *endolymph*; in this fluid there are found floating minute hard particles, which are called *ear-dust*, or ear-stones. In the ampullæ, too, are numerous stiff hair-like processes, which grow out from the cells lining the walls of those dilatations.

A fluid surrounds the membranous structures, keeping them away from the bone; this is called the *perilymph*.

Part of the nerve of hearing spreads out upon the

walls of the utricle, the saccule, and the ampullæ of the membranous semicircular canals.

We must now proceed to examine the other portion of the internal ear. The word *cochlea* means "the snail's shell;" and this part of the ear receives its name from its resemblance to that object. It is a passage excavated in the hard bone of the head in such a manner as to coil round upon itself two and a half times, and to leave a bony pillar, called the *modiolus*, standing straight up in the midst of the coils. This is the *spiral canal*. Its twists become smaller by degrees, and end at the top in a closed dome. Perhaps you will understand better what is meant by the canal being coiled "upon itself," if you will look into a snail or a periwinkle shell.

But the one passage which is produced by this spiral arrangement is divided into three parts in the following manner;—First of all, there is a thin piece of bone, called the spiral plate, fastened on to the modiolus by one edge, and winding round it just as many times as the spiral canal does. If this spiral plate went right across from the modiolus to the side of the cochlea, you will see that it would divide the canal into two parts only. But it does not run right across; it stops just about half-way over. Then two membranes arise out of it, and stretch over the rest of the way to the opposite wall. Of course, those edges of these membranes which are attached to the spiral plate are close to each other; but they at once diverge, or spread out, so that their other edges are attached to the opposite wall at a considerable (microscopic) distance from one another. The result of this is that the original spiral canal is divided into three parts, that which is enclosed by the membranes running from the spiral plate being triangular in shape. That one is also the central canal of the three; and for this reason it is called the *scala media*—middle passage. The passage on the lower side of it is called

the *scala tympani*, because the round window leads into it, and if there were not membrane filling up that opening there would be a free communication between the tympanum and the scala tympani. The passage over the scala media is called the *scala vestibuli*, because it opens into the vestibule; and the oval window, with the stirrup bone fastened to it, leads from the tympanum into the vestibule. So that any movement of the air in the drum must affect the *scala tympani* through the *round* window, and the *scala vestibuli* through the *oval* window. All three scalæ are filled with the same fluid as that in the semicircular canals.

The scala media ends blindly a little below the dome of the cochlea; the consequence of this is that the scalæ vestibuli and tympani have no longer a partition between them, and therefore freely communicate with each other. The bottom end of the scala media communicates with the vestibule by a narrow pipe.

Fibres of the auditory nerve are distributed along the whole of the walls of the scala media, as well as to the ampullæ of the semicircular canals, and to the vestibule. That membranous wall which separates the scala media from the scala tympani has a great number of minute rod-like bodies, called *fibres of Corti*, set upon it in such a manner as to look like the keys of a piano. The final terminations of the nerve of hearing are believed to be connected with these bodies, which are moved by the slightest impulse.

It only now remains to describe how the vibrations of air which make sound, reach and affect the ends of the auditory nerve, so far away from the exterior of the head where the sound arises.

All bodies which give out sound are in a state of vibration or tremulousness, and throw the air which surrounds them into waves. The aerial sound waves enter the external auditory passage, and strike upon the tympanic membrane, setting it vibrating in its turn. The

vibrations of the tympanic membrane have two results—first, they throw the air which is inside the drum into waves, which pass over and strike upon the membrane filling in the round window; and secondly, they move the end of the hammer, which in its turn pulls the anvil, and that again moves the stirrup, which has its end fastened in the membrane filling in the oval window. The sound-waves are thus passed on through the membranes filling the windows to the fluid which is in and around the membranous labyrinth and the cochlea. The fluid, with the ear-dust contained in it, is by this means agitated, and strikes against the spread-out ends of the auditory nerve. The nerve carries the impulse which it has received up to the brain, where we become conscious of the vibrations, and where they are distinguished as sounds.

It is believed that the membranous semicircular canals and vestibule have the power of telling the brain whether a sound is loud or the reverse, but that all distinctions of tune and harmony, all the difference between a sweet and a harsh voice, between the glorious strains of a Mozart and the howls of a benighted pussy, are recognised by the cochlea alone. If this be true, the wall of the scala media has not only the same appearance but also the same office as the key-board of a piano. Each one of the rod-like fibres set upon that wall must be attached to a single filament of the auditory nerve, and must be set in motion by a given vibration and by no other; so that if we could directly agitate any one of the fibres we should produce a single musical note in the brain, just as one is produced by striking a key on the piano. And it is the general opinion of physiologists that this is the truth.*

* It is right, however, that I should mention that there is some doubt still about the exact functions of these minute portions of the labyrinth, and that this must only be received as a highly probable hypothesis.

Sound vibrations pass through the air at the rate of 1,100 feet a second. Light travels no fewer than 186,000 *miles* in the same time. Hence we see the flash of the lightning some seconds before we hear the roll of the thunder.

Deafness is sometimes caused by hardening of the *ear-wax*, the secretion which lubricates the tympanic membrane and the external passage, and which is formed by little glands in the wall of the meatus. This affection is generally readily cured by proper treatment. Deafness following a shock to the ear may be the result of rupture of the membrane of the drum, and any lotion applied to the ear in such a case would probably do great mischief. The Duke of Wellington had the tympanic membrane of his left ear ruptured by standing just in advance and a very little to one side of a great cannon while it was discharged; and a solution of lunar caustic being put into the ear, incurable deafness and long suffering resulted. Rupture of the drum may be caused by "boxing the ears."

Dr. Abbotts Smith maintains that deafness often results from bathing, because water runs into the external meatus when the head is dipped, and, as it cannot be thoroughly removed thence with the towel, evaporates slowly, causing chill and perhaps inflammation; and he advises filling the ear with cotton-wool to prevent this mischief. To people who suffer from earache such caution may be very serviceable.

The sense of *Touch* belongs to the whole surface of the skin. The nerves end, as described in a preceding chapter, in little conical elevations, called papillæ, the result attained by this arrangement being a greater extent of nerve surface. The acuteness of the sense varies very much in different parts of the body. If a pair of compass dividers are applied to the thigh, the two points cannot be distinguished unless there is three inches

distance between them; while upon the tips of the fingers, the points will be felt as two until they are almost close together. Upon the thigh, the back of the neck, and other places where the sense is not acute, the nerves do not end in papillæ, but merely form a flat layer of the skin.

Touch, in common with all our senses, may be cultivated to a very high degree. The blind acquire many useful trades, and a tactile acuteness generally which is very remarkable. But, perhaps, the rapidity of a weaver's movements, or the fineness of touch by which a skilled surgeon performs operations without any aid from sight, are even more instructive examples of the power of culture. So great are our possibilities of development, that we should never say that we cannot do anything. In manual as in mental work, almost anything may be accomplished by trying long enough.

The sense of *Taste* resides in the tongue and the back part of the palate. The nerve of taste ends in these situations in papillæ very similar to those of the skin. They are distributed most thickly, and are largest in size, toward the back of the tongue. The uses of taste in enabling us to choose our food, and to guard against swallowing acrid and violent poisons, are very clear. But no other of the senses is so liable to be perverted from its natural excellence as is this one. Animals in a state of nature seem always able to select safe and proper foods for themselves, by means of taste and smell combined. But with all man's superiority, this is beyond his power; and Robinson Crusoe on his island had to learn which of the fruits of the land were not poisonous by watching the choice of the birds of the air. To us the chief use of the sense of taste is to give pleasure in eating. It is necessary for our existence, and is, speaking generally, an important fact, that the proper performance of all those functions of animal life which are not

mechanical, but dependent upon our volition, will be rewarded by pleasure; and conversely, that our neglect of any of our bodily capacities shall be punished by pain. Were it not for taste and hunger, we might be in danger of letting ourselves perish from inanition.

The sense of *Smell* resides in the upper and back part of the nose. The partition which is seen between the nostrils below continues throughout, dividing the nose into two distinct cavities, that rise from the hard palate, by which they are separated from the mouth, right up to the root of the nose between the eyes. There are two back openings of the nose, just as there are two in front; the posterior nostrils leading into the throat, so that air can enter the lungs through the nose as well as through the mouth. The nerve of smell—the *olfactory* nerve—spreads out upon two small scroll-like bones in the upper and back part of the nasal cavities. All substances which have any scent give off actual particles of solid matter, which enter the nose, and excite the ends of the nerve, by which the sensation is carried to the brain, where it is recognised. It is very wonderful that particles so minute that we cannot see them with the most powerful lens, nor find any lessening in the weight of a substance which has given off millions of them, should yet have so real an existence, and so undeniable an effect upon ourselves.

Smell warns us against breathing bad air and injurious gases. Unpleasant smells do not necessarily and always imply that the air is dangerous to health, but they do so generally.

The senses of smell and taste are very intimately connected. In some animals they are actually conjoined through openings leading from the palate to the nose; and we ourselves may much disguise the flavour of nauseous medicines by stopping the nose while drinking them.

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# CHAPTER XII.

## THE BRAIN AND NERVES.

THE organs of sense described in the last two chapters were seen to be in every case merely an elaborate apparatus for receiving outer impressions and conveying them to the brain. In the eye, the ear, the nose, the mouth, and the skin, we found invariably that a nerve which had its rise in the brain terminated by dividing into fine and spread-out fibres, and that when a given stimulus was applied to those nerve-fibres, through the mediumship of the special organ of sense, the excitement was carried up to the brain, where it was interpreted into a definite sensation. Thus, we may compare the organs of sense, such as the eye and the ear, to the doors of a house, and the external stimuli—the waves of light, of sound, etc.—to visitors, who enter through the doors, and are received by a servant, who answers to the spread-out nerve-fibres, and conducted along the corridors formed by the nerve itself into the presence of the master of the house—the brain; to be by him received, and scrutinised, and treated according to their character and importance.

It is the Master of the House that forms the chief subject of this chapter. And indeed this name may be fitly given to the brain apart from the metaphor; for it is the head and centre of the nervous system, and by that system every movement of every organ of the body is directed and controlled.

The brain itself, however, does not *directly* rule all

parts of the body. If the organs upon whose ceaseless activity our life depends were under the immediate control of the brain, if our consciousness had to govern their action, we could think of nothing but our own existence, we could care for nothing but our own incessant wants, we might never sleep nor rest. This consideration at once suggests that the nervous system must be divided into two parts—one to attend to the grosser functions of organic life, and one to carry on the higher operations of the mind and to command all those actions which are under the direction of our will. Such a division really exists. To return for a moment to our illustration: the master of the house does not interfere with the lower household routine, which is committed to the care of a staff of competent servants; his own attention is sufficiently taken up in directing matters which are *not* routine, in giving orders about unforeseen occurrences, in receiving guests (such as the impressions from the sensory organs), and in intellectual labour and social relations.

Those nerve-centres and nerves which are the servants who manage the routine work, make up what is called the *sympathetic system;* the master of the house and the servants in immediate attendance upon him—in other words, the brain and spinal cord with the nerves arising from them—make up the *cerebro-spinal system.*

It must not be supposed that there is a complete division between these two parts of our nervous organisation; on the contrary, as will be seen, there is a most intimate connection between them. But still, there is a broad distinction between the sympathetic and cerebro-spinal centres and nerves, both in function and in arrangement, which makes it most convenient to study them apart from each other.

The centre of the *Sympathetic System* consists of two rows of little round lumps of nerve matter, one of which

rows runs down on each side of the backbone. The nerve lumps are called *ganglia*, and they contain nerve-cells, of which you will hear more later on, in their substance. They are not placed close together, but each a little distance below another; and cords of nervous matter run between them, so as to connect them, and form the rows into chains of ganglia. Nervous cords also pass into the ganglia from the spinal cord, thus exemplifying what was stated above—that there is an intimate connection between all parts of our nervous organisation.

Nerves are given off from these central sympathetic ganglia, and are distributed to most of the internal organs of the body that are not controlled by the will, regulating the exercise of their functions. The heart beats quickly or slowly, the stomach digests, the intestines move, and the glands secrete, through the agency of these nerves. They usually accompany the blood-vessels, and, by regulating the degree of contraction of the coats of the arteries, they govern the flow of blood to any given part, and the heat and growth which depend on the blood supply. In some parts of the thorax and abdomen the fibres form a network, or *plexus*, in the midst of which are found ganglia.

The name "sympathetic" is given to this nervous system, because it is believed that through its agency distant organs have sympathy with one another's afflictions. Thus, for example, severe pain in any part of the body will cause some sensitive persons to be sick; mental emotion will disorder the liver and other secretions; and a blow over the stomach may stop the heart.

The *Cerebro-spinal System* is much the more elaborate in structure, as well as the more important in office. It consists of the brain and the spinal cord, and the nerves which arise from them both. The brain, as everybody knows, lies within the skull. The spinal cord is enclosed inside the backbone.

The brain is contained in the "strong room" of the house; we might guess the value of this precious jewel by the care with which it is enshrined. Just hear how many coverings it has for its protection. Outside all, there is the hair of the head; then comes the scalp. Under this is the skull, a case formed of very hard strong bones firmly jointed together. This bone is lined inside by a tough thick skin, or membrane, called the *dura mater*. Then come two layers of a smooth delicate serous membrane, called the *arachnoid;* these two layers become adherent to each other at certain parts, so as to form a shut bag; and contained between them, in the bag as it were, is a liquid, called the *arachnoid fluid*. This is the usual seat of "water on the brain." Beneath the lower layer of the arachnoid is another membrane, very delicate and containing many blood-vessels; this is the *pia mater*, and it coats the substance of the brain. A small quantity of fluid also intervenes between the arachnoid and the pia mater; so that the brain is protected by lying beneath no fewer than nine coverings.

The dura mater, the arachnoid, and the pia mater membranes are all found enveloping the spinal cord, inside the backbone, just as they do the brain.

Nerve-matter, of which is composed the whole of both the sympathetic and cerebro-spinal systems, is a watery pulpy substance. There are two kinds of it, *grey* and *white*. When it is examined under the microscope, it is found that the *nerve-centres* (that is, the brain and cord, and the ganglia) are made up of oval and star-shaped *cells*, and of *straight fibres also*, while the *nerves* (that is, the cords which run from the centres) are composed of *fibres alone*. Nerve-matter contains albumen, fat, and phosphorus. A deficiency of any one of these ingredients may cause various nervous disorders. The quantity of phosphorus in nerve-matter appears to vary with the use of the brain. Hard study works it up, and

throws it out into the blood. There is more of it in the nervé-matter of people in the full prime of their mental powers than in that of idiots, of infants, or of aged persons. We take in the phosphorus required by our brains, as we take in all our salts, in various articles of diet; among those which contain most of it may be mentioned oatmeal, apples, and shell-fish, especially lobsters. Doctors frequently relieve nervous complaints by prescribing chemical preparations of phosphorus; but it should only be so taken when and as ordered by a properly qualified physician, for in excess it is poisonous, and if taken at all in unsuitable cases it is injurious instead of beneficial.

The spinal cord is continuous above with the brain, and terminates below in a point at the second loin bone of the spine. It is made of both grey and white matter, the former being inside and the latter outside. The cord is nearly divided into halves from front to back by two deep fissures — the *anterior* and the *posterior fissures*, which leave only a narrow bridge of the grey matter to connect the right and left sides of the cord; and a minute tube, the *central canal*, runs down the middle of even that narrow bridge. The grey matter is arranged inside the white in the shape of a crescent in each half of the cord; the backs of the two crescents are turned to each other, and are joined by the bridge left at the bottom of the fissures, as just described (Fig. 24).

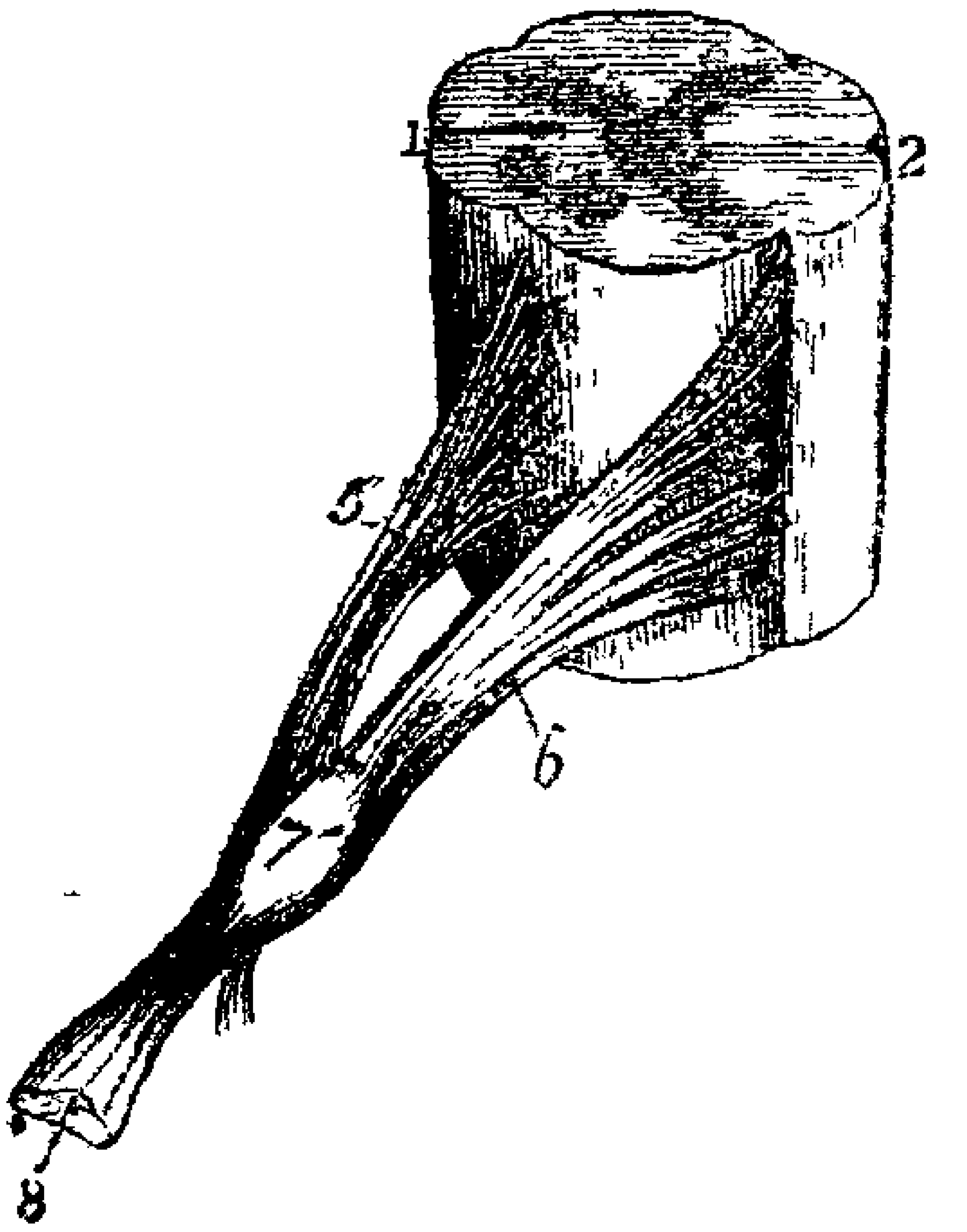


*Fig.* 24.—Portion of the spinal cord, with a spinal nerve; 1, the anterior fissure: 2, the posterior fissure; the half-moons of grey matter, meeting at their backs, are here seen; 5. the anterior roots; 6, the posterior roots of 8, a spinal nerve; 7, the ganglion of the posterior root.

*Thirty-one pairs* of spinal nerves run from the spinal cord to all parts of the body. A number of delicate nerve filaments arise in *two* straight lines down *each* half of the cord; one line on either side of the posterior fissure, and one line on either side of the anterior fissure (Fig. 24, 5, 6). These are the roots of the spinal nerves. Those filaments which arise nearest to *each* side of the front fissure are called the anterior roots; those which are nearest the back are the posterior roots. A certain number of the roots join together, and form *bundles.* The posterior bundles each present a small swelling, which is called the ganglion of the posterior root. Then one anterior and one posterior bundle join together, and make up the *trunk of a spinal nerve*, which issues from the backbone through a small opening provided for each one. Since thirty-one of these trunks run from each side of the cord, there are in all sixty-two spinal nerves. They divide and subdivide, their final terminations going into the muscles and the skin. We will defer the study of the functions of the spinal cord and nerves until after we understand the structure of the brain.

The top part of the cord passes into the lower part of the brain. The brain is divided into three parts:—the *cerebrum*, the *cerebellum*, and the *medulla oblongata* (Fig. 25). The latter is a mass of nervous substance, wider above than below; and it is into this that the spinal cord passes. The central canal of the cord widens out in the medulla, and forms a cavity which is called the *fourth ventricle.*

Above and to the back of the medulla is the cerebellum, or little brain. The grey and white nerve-matter has a different arrangement in the cerebellum from that which was seen in the cord. There the grey matter was inside the white; here the position is exactly reversed. When the cerebellum is cut down through the middle lengthways the white matter is seen spreading out inside

the grey so as to look just like the stem and branches of a tree. This is called the *arbor vitæ*—the tree of life.

I remarked that it would be seen that all the parts of our nervous organisation are intimately connected with each other. We have already seen that fibres run

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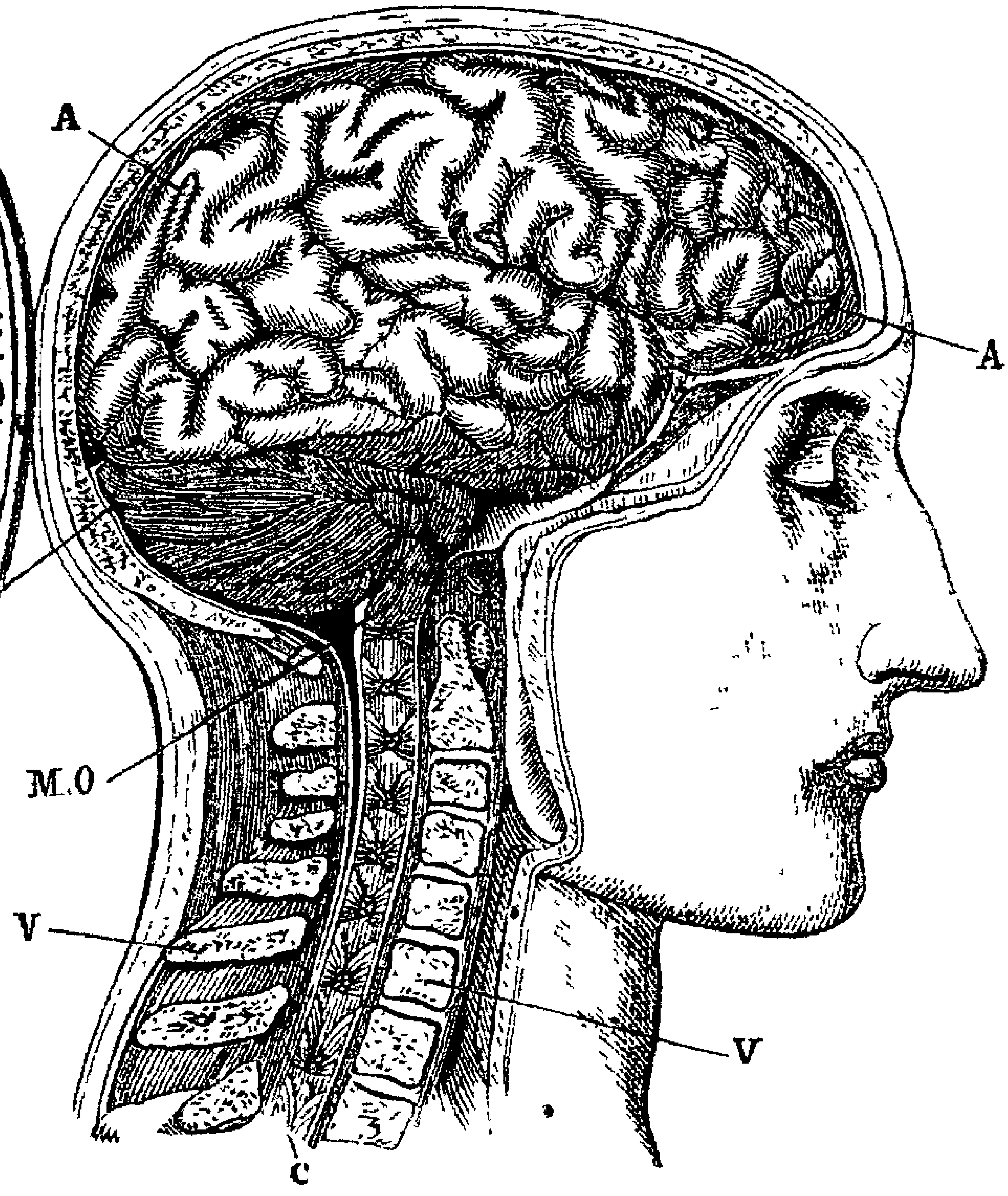


*Fig.* 25.*—The Brain and Spinal Cord in Position (side view).

A, the cerebrum; B, the cerebellum; M.O., the medulla oblongata; V, the vertebræ, cut in halves; c, the spinal cord, and the origin of its nerves.

between the spinal cord and the sympathetic ganglia; and that the cord runs up and merges into the medulla. Now we shall notice how all the parts of the brain communicate with one another.

The cerebellum sends down on each side several layers of nervous fibres, which meet and join together at

* From Bourgery.

the under side of the brain, so as to form a kind of bridge across the medulla. This is the *pons varolii.* Then the nervous fibres of the medulla pass forward and intermix with those from the cerebellum which form the pons; appearing again on the opposite side of this bridge in two broad bundles, which are called *crura cerebri.* Fibres from the crura cerebri pass on farther toward the front, and enter two other large masses of nerve substance, which are called the *optic thalami.* Between these two latter masses is a small cavity, called the *third* ventricle, communicating with the fourth ventricle by a narrow passage. The *pineal gland* and the *pituitary body* are peculiar prolongations out of the third ventricle. The front of the third ventricle is partly closed by a thin layer of nervous matter; but in each end of this there is an oval aperture by which the third ventricle opens into two other larger cavities, called the *lateral* ventricles, and situated actually in the cerebral hemispheres—that is in the top part of the brain. The greater part of the floor of the cavities of the lateral ventricles is formed by a mass of nervous matter named the *corpus striatum* (striped body) into which there pass fibres from the crura cerebri.

Those who cannot follow this detail can yet notice and remember the interesting fact that all these separate nervous masses are closely connected with each other by fibres running from one to another.

All the parts just described are situated at the base of the brain, somewhere about the level of the top of the ear. Overhanging them, and extending right up to the top of the head, is the great mass of the brain, the *cerebrum.*

The cerebrum is divided by a fissure down the centre (Fig. 26) into two hemispheres, right and left, and each hemisphere is again marked off into three lobes. The partition down the middle of the brain is not quite complete; at the bottom of the fissure the hemispheres are connected by a band of fibres, called

the *corpus callosum.* The corpus callosum forms the

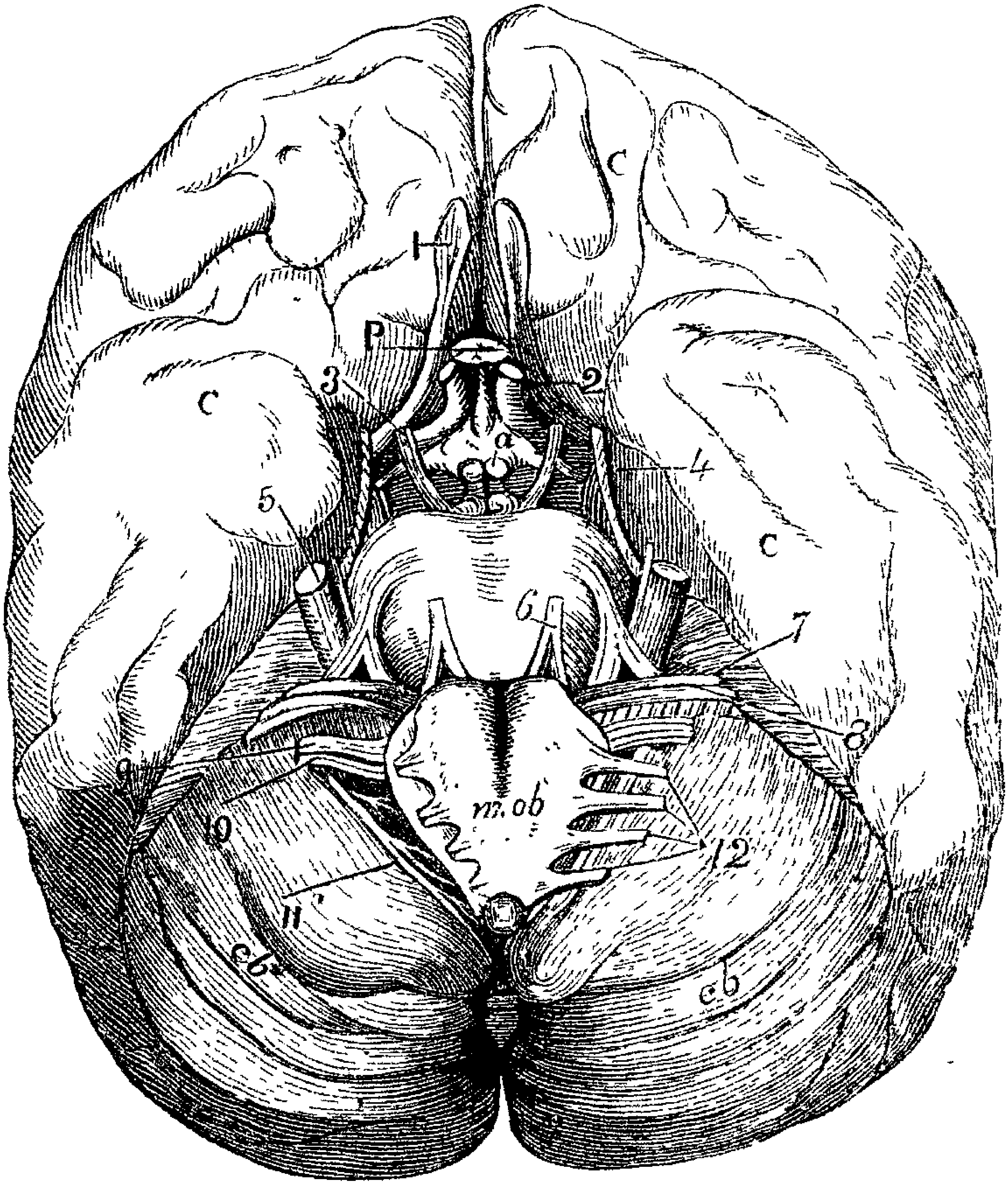


*Fig.* 26.*—THE BASE OF THE BRAIN.

C, the under surface of the cerebrum; *cb*, the cerebellum; *m.ob*, the medulla oblongata. The nerves are numbered 1 to 12. 1, the olfactory nerve; 2, the optic; 3, 4, and 6, nerves which govern the muscles of the eyeball; 5, the trigeminal, which arises as shown by two roots; 7, the facial; 8, the auditory; 9, the glosso-pharyngeal; 10, the pneumogastric; 11, the spinal accessory; 12, the several roots of the hypoglossal. The figure 6 is placed on the pons varolii; the crura cerebri are between the third and fourth nerves on either side. Just above are *a*, the corpora albicanta, and P, the pituitary body.

roof of the lateral ventricles, which were described

* After Bourgery.

above. The outer surface of the cerebral hemispheres is twisted and convoluted very much, by which means the extent of surface is increased. The grey matter in the cerebrum is, as it is in the cerebellum, outside the white; so that the effect of the convolutions of the surface of the hemispheres is to increase the proportion of grey to white matter. The cerebrum weighs about six times as much as all the rest of the brain together.

Twelve pairs of nerves are given off from the brain, and go to supply the upper part of the body with sensation and motion, just as the spinal nerves go to the trunk and limbs. Ten of the twelve arise from the medulla oblongata; two only from the more central part of the brain.

The first pair of nerves are the *olfactory*, those through which we have the sense of smell. This nerve is really a part of the cerebrum itself, a prolongation forward of the substance of the hemisphere. The excitation of the nerve of smelling is, therefore, carried more directly and immediately to the higher brain than any other nerve stimulation is; although, from the intimate connection that exists between all portions of the brain, it is clear that any agitation of one part must be conveyed to some extent to all the others. Now, it is within the experience of all of us to some degree, that "memory, imagination, old sentiments and associations, are more readily reached by the sense of *smell* than by almost any other channel." Nearly every grown-up person has some special little experience of his own, proving the truth of this observation. A thought of "long ago" enters the mind with a sudden irresistible rush when a peculiar odour, not too frequently met with, affects the nerve of smell. The professor of physiology in Harvard University, Dr. O. W. Holmes, in one of his wise books, suggests that "there may be a physical reason for this

strange connection between the sense of smell and the mind. The olfactory nerve is the only one directly connected with the hemispheres of the brain, the parts in which, as we have every reason to believe, the intellectual processes are performed. Whether this anatomical arrangement is at the bottom of the facts I have mentioned, I will not decide, but it is curious enough to be worth remembering. Contrast the sense of taste, as a source of suggestive impressions, with that of smell. Now, you will find the nerve of taste has no immediate connection with the brain proper, but only with the prolongation of the spinal cord"—the medulla.

The only other nerve beside the olfactory arising from the brain itself is that of sight—the optic nerve. This pair is the *second*, and arises from the optic thalami.

The remaining ten all come from the medulla oblongata. They are numbered and enumerated in their order, continuing backwards.

The *third*, *fourth*, and *sixth* pairs all go to supply the muscles which move the eyeball.

The *fifth* pair is the largest of the whole number. It is called the *trigeminal*, or three-twins nerve, because on each side it separates immediately upon its origin into three great branches. It supplies the skin of the face, and the muscles of the jaws.

The *seventh* pair are distributed to the muscles of the rest of the face, and are hence named the *facial*.

The *eighth* pair are the nerves of hearing—the *auditory* nerves.

The *ninth*, the *glosso-pharyngeal*, are the principal nerves of taste; but they also supply the muscles of the back of the throat.

The *tenth* pair are two very important ones; and they are the only cranial nerves which travel far away from the place of their origin. They are the *pneumogas-*

*tric* nerves. Fibres of them go to the organs of voice, the heart, the lungs, and the stomach, exercising great influence upon the action of all these parts. Thus, for instance, although the contractions of the heart are not caused by the pneumogastric, yet irritation or injury to the nerve will stop the heart.

The *eleventh* pair of nerves are called *spinal accessory*, and supply various muscles about the neck. The twelfth and last pair, the *hypoglossal*, cause the contraction of the muscles which move the tongue.

As might be inferred from the fact that so many nerves arise from it, the medulla oblongata is an extremely important part of the cerebro-spinal centre. A slight puncture in one side of the fourth ventricle is sufficient to cause the disease called *diabetes*. A greater injury to the medulla may destroy life by paralysing the muscles of the chest which produce respiration; and if the roots of the pneumogastric nerves be affected by the injury, death will ensue from the arrest of the heart's action.

The functions of the remainder of the brain and of the spinal cord must be considered in the next chapter.

# CHAPTER XIII.

## THE WORK AND THE HEALTH OF THE NERVOUS SYSTEM.

SENSATION and will belong to the brain. Whenever we feel any sensation, or whenever we make any voluntary movement, we do so because there has been brain action. We know that this is the case, because, when a nerve going to a given part of the body is cut through, so that it can no longer carry messages to and from the brain, there is no sensibility to pain in the part, nor can the muscles be made to move by voluntary effort.

The thirty-one pairs of spinal nerves are distributed in fine filaments to the muscles and the skin of the trunk and extremities. Movement is produced in the body, as you know, by contraction of muscle. Now, if the trunk of a spinal nerve be irritated, all the muscles to which its fibres go will contract, and the skin which it supplies will suffer pain. This is the same effect that would be produced by irritation of the spread-out fibres themselves. For instance, suppose that the palm of the hand were accidentally laid upon a plate of hot iron; instantly pain would be felt, and the muscles would contract so as to snatch the hand away: but if the hot iron had been applied directly to the trunk of the spinal nerve which supplies the palm of the hand with fibres, the result would have been just the same; there would have been pain felt, and the muscles would have contracted in just the same manner.

The trunk of a spinal nerve, you will remember, is

formed by the joining together of its anterior and posterior roots. The effect described above is produced when any part of the *trunk* is irritated; but when the irritation is applied to *either one* of the roots, only half the result is produced. If the anterior root be pinched or burned, no pain is felt, but the muscles to which the nerve is distributed contract. On the contrary, if the posterior root be irritated, pain is felt all over the skin to which the filaments go, but there is no contraction of the muscles. Similarly, if the anterior roots of a spinal nerve be cut through, the animal can feel pain in the part to which the trunk of the nerve sends fibres, but cannot move the muscles. Or, if the posterior root is injured, the sensibility of the part to which the nerve goes is lost, but the muscles remain under the control of the will. If both roots are destroyed, then there is neither sensation nor voluntary motion.

It is clear, therefore, that the anterior root supplies the contracting or *motor* power, and the posterior root the *sensory* power; and all sensory impulses coming from without must enter the spinal cord by the posterior roots, while all orders for movement of the muscle must leave the cord by the anterior roots of the nerve trunk. It helps us to remember "which is which" to notice that the initial letters of the root and its action together are very familiar to us in other connections. Thus:—

Anterior—Motor: A.M.

Posterior—Sensory: P.S.

The first two letters we use, you know, when we are talking about the time of day before noon; and the other two when we want to add something to a completed letter.

Sensory nerves are called also *afferent* nerves, from a root meaning to carry to; and motor nerves are termed *efferent*—to carry away from.

It is clear that there is an actual something passed along the nerve when these effects are produced. Precisely what that is we do not know. It is considered probable that there occurs a change in the arrangement of the molecules of the nerve-fibres. But we can only say that the impulse travels by nerve-force. There is certainly some relationship between nerve-force and electricity; but the former travels very much more slowly than the latter. It does not appear to us that any interval elapses between a touch being laid upon our hands, and our becoming conscious of the fact. But in reality there is quite an appreciable time, nerve-force travelling very much more slowly even than sound.

There has not yet been any evidence given you that impulses must reach the brain to awaken sensation and will. Experience, however, supplies such evidence. If the spinal cord be cut across, or so crushed as to destroy the power of a small portion of it, sensation and voluntary motion no longer exist in those parts of the body which are supplied by nerves arising below the point of injury to the cord. Men have been stabbed in the back, and have crushed the spine in part by falls; and in these cases they always retained the power of moving and of feeling in those parts of the frame which were connected with the brain through the cord, but were completely paralysed in those parts which were separated from the brain by being connected with the cord at a point below the injury. These cases show conclusively that volition and sensation belong to the brain.

But the same cases give another piece of valuable knowledge. Suppose the cord to be cut in the back so that the man cannot move his own legs by his will, nor feel when they are pinched and galvanised. Still, if the soles of the feet be tickled, the legs will be violently drawn away and kicked out; and a galvanic shock will cause more vigorous motion than the will could do, notwithstanding

that the man only knows that his feet are irritated, and that they move because he can look down and see what happens to them.

From this we learn that the cord is not only a great nerve to carry sensations to and bring back orders from the brain, but has also more important functions of its own. This power which the cord in itself possesses of receiving sensory impressions and converting them into movements is called *reflex action.* The impulse is *reflected* from the sensory to the motor nerve-root.

The next important and interesting point to notice is that sensory impulses going through the cord, cross over and pass up to the brain through the *opposite* half of the cord from the side of the body at which they originate; in other words, if the *right* side is hurt, the *left* half of the cord carries the news of the injury up to the *left* side of the brain. Motor impulses, however, come down through the half of the cord corresponding to the side which they will affect.

This is known by the following fact. If the right half of the cord be cut completely through, down to the bridge, the left half remaining untouched, irritation of the skin of the right side of the body below the cut will cause pain, but the muscles of that side cannot be moved by the will. This shows that the sensory impulses cross over to the opposite side of the cord directly they enter it, but that motor impulses come down from the brain on the side which they are to affect.

The motor nerve-fibres also cross over, however, at the medulla oblongata. They can be seen running from side to side at that situation, forming what is called the *decussation of the anterior pyramids.* Thus, the right half of the brain governs the left half of the body, and *vice versa.*

The medulla oblongata, as might be judged from the number of principal nerves arising from it, is an extremely important part of the brain in its relation to the rest of

the body. The cerebrum may be much mutilated without death ensuing; but a comparatively slight injury to the medulla must implicate the root of the pneumogastric nerve, and so stop the heart or paralyse the muscles of respiration.

Science has yet much to learn respecting the work and the action of the upper parts of the brain, especially as regards the *cerebellum*. This portion of the brain is held to be the main director of co-ordinate movements; but what other functions it may possess cannot be said yet to be certainly known. It is, however, certain that the *cerebrum* is the seat of all those faculties which make up what we call the mind. An animal may continue to live a merely vegetative existence when the hemispheres are almost removed; but a slight alteration in their physical structure, the pressure upon them of a little piece of bone, or a small tumour, may disorganise the machine, and lay the most towering mind in ruins.

It has already been shown that *volitions* and *sensations* belong to the brain. These mental processes are classed with *thoughts* and *emotions* as *states of consciousness*. We can neither think, nor feel, nor suffer and enjoy, nor will to act or be still, without being conscious of our existence. But we cannot explain the fact. As Professor Huxley says—"What consciousness is, we know not; and how it is that anything so remarkable as a state of consciousness comes about as the result of irritating nervous tissue is just as unaccountable as the appearance of the Djin when Aladdin rubbed his lamp."

Mental power is, to some extent, determined by the size of the brain. The average weight of the brain in man is forty-eight ounces; but in men of great mental ability this quantity has been far exceeded. The brain of Cuvier, the great anatomist, was found to weigh sixty-four ounces. That of Dr. Abercrombie was sixty-three ounces; and that of Baron Dupuytren, the eminent

surgeon, was sixty-two and a half. The hats of ten gentlemen were tried upon the skull of the poet Burns, and the only one of the ten which could cover it was the hat of Thomas Carlyle. Sir James Young Simpson—who began his career as a baker's boy carrying a bread basket, and was disappointed in love because he was too poor a suitor for a working carpenter's daughter, but who lived to discover chloroform and to write priceless medical treatises, and who died a baronet, a professor in Edinburgh University, and a physician to the Queen, and who was followed to his grave with mourning by half the population of the Scotch metropolis—had a brain of fifty-six ounces. Lord Campbell's brain weighed fifty-three ounces.

The number and depth of the cerebral convolutions seems, however, to have more to do with the mental power than the mere bulk has. The experienced anatomists who opened Sir James Simpson's head declared that they never before had seen a brain so twisted and convoluted. The convolutions are absent from the brains of some of the lower orders of the mammalia, and increase in number and complexity according to the scale of intelligence. They are more numerous in man than in any other animal, giving to him a surface of grey matter six hundred square inches in extent. There are fewer convolutions in infants than in adults.

In estimating the intelligence of an animal by the bulk of its brain, it is necessary to take into account the size of the whole body. If *actual* instead of *relative* weight were noted, we should have to conclude that the whale and the elephant were mentally superior to man. The brain of a whale seventy-five feet long weighed seventy ounces; that of the elephant averages eight to ten pounds. But the whole body of these animals weighs immensely more than that of a man does; and it is essential that we take this relationship between the weight

of the organ and of the entire frame into account. So, also, women are more slightly made and less heavy than men, and therefore the *absolute* weight of the female brain averages about, three ounces less than the male. When the *relative* weight of body and brain are calculated, the human family are found to be far above all other animals. In man, the brain is to the body in weight as 1 to 36; in the other mammalia (animals which have four limbs and suckle their young), 1 to 186; in birds, 1 to 212; in reptiles, 1 to 1321; and in fishes, 1 to 5668.

But sooner than in any other part of our study do we here arrive at "the threshold of that valley of humiliation into which only the wisest and best men can descend, acknowledging themselves to be but children gathering pebbles on the shore of an unfathomable ocean." Sooner here even than at all points, we reach the limit of what *is* known, if not of that which *can be* known to us. For instance, nobody can explain the wonderful phenomena of memory. That memory is a faculty possessed by the brain is certain; for disease or injury of the organ will destroy the power of recollecting. But how we hold facts for years, and often unconsciously, bound up in the folds of the brain is practically a mystery. The only attempt at a theory (and it is one to which many obvious objections may be raised) is that memory is dependent upon the "development of a group of nerve cells and fibres constituting one connected system," to use Dr. Carpenter's words; that is, that a special little bit of brain is built to enclose every fact that we remember!

Whatever may be thought of this theory, we must take into consideration the wonderful truth that it seems almost as though the mind never lost any knowledge which it had once acquired, although the power of reproducing the information may be lost. The "cases" in medical history which go to prove this are very numerous.

A Welshman was admitted into St. Thomas's Hospital suffering from an injury to the head. Before his accident he had forgotten his native tongue completely; but while he was in the hospital he could speak nothing but Welsh; and again, as soon as he recovered, he lost all remembrance of that language, and returned to talking English. Dr. Rush mentions a French countess who spoke during a fever the language of Lower Brittany, which she had learned when young, but had never used for many years. In one instance, a person who was acquainted with several languages, forgot one of them entirely after an illness, while he remembered all the others. Several cases are recorded in which a blow or a fall made men suddenly remember the dead languages learnt at school; and on the other hand, in more than one case, Latin was completely forgotten for a time after an injury, and returned to the memory all in a moment. Perhaps the most extraordinary instance of the power which the brain has of retaining, though not at will reproducing, what it has once received, was that of an unlettered servant girl, who, upon her death-bed, poured forth a flood of words in strange tongues. The Greek and Latin of "Fathers of the Church," and scraps in Hebrew from ancient Rabbinical writings, fell alternately from her lips; and the case was set down by the clergy as one of possession. But her previous history was carefully investigated by a celebrated writer on the mind, who was much interested in the remarkable occurrence, and it was discovered that the girl had been for some years in the service of a learned divine, who had been in the habit of walking up and down the passage that led between his study and the kitchen reading aloud to himself certain parts of the Fathers and Rabbinical writings. In this case, the singular sounds had been received unconsciously into the girl's brain, and had remained there, without any meaning attached to them, until the diseased blood

producing delirium brought them forth on her lips without her volition or knowledge.

It is a curious fact, also, that memory is often excellent in those whose mental powers generally are very inferior. Dr. Spurzheim gives several cases in one of his works of idiots who had remarkable memories. One idiot boy whom he saw could repeat long passages from the Bible after hearing them once read, and without understanding them in the least.

Education and use of the brain strengthen it, and increase its power:

> "The brain is like the hand, and grows with using."

Moreover, impressions made upon the mind in early life are both more readily received and more completely retained than those impressions which come when the growth of the brain is far advanced. For this reason, education is begun early in life, so that the trained intellect in youth may be ready and vigorous. It is beyond question that the brain is stronger in adult life, and the capacity for any kind of employment is greater, when education has been carried on throughout childhood. To put the same fact in another way: if we could find two children born with exactly the same natural capacity —the same quantity and quality of brain—and educated one of them from the age of three or four upwards, leaving the other to run wild about the world; in mature life, the one who had been to school would not merely have a head full of facts of which the other had never heard, but would likewise be a far better workman in whatever they might both undertake, and a far more worthy citizen of a free country, than he who was ignorant. Education for every child is, therefore, an object for which it is worth while for us all to make some sacrifices.

There is, however, a serious danger for individuals to be guarded against. In the circumstances in which

we live, with every-day illustrations of the adage, "Knowledge is power," and with so wide-reaching a system of examinations and educational honours, there is very often more danger of health being destroyed by over-working the brains of the young, than of their cultivation being neglected. The body is developed before the mind. Our muscles, bones, and other organs have attained their full formation when we are twenty; the brain continues to grow a little up to the age of forty. Moreover, the health of the mind depends so much on the vigour of the body, that it is very mistaken to hope to have the one in a high state of perfection if the other is neglected and weak. Dr. Elizabeth Blackwell wisely writes:—"The guiding principle of health-education is to follow the order of nature, and place the strengthening of the physical powers not independently of, but in advance of, the mental powers. If the order is reversed, and the immature mind be allowed to tyrannise over the immature body, and disturb the proportion of nature's work by withdrawing too much creative force to the mind, the true relations of mind and body can never be restored."

Sleep is a most important point in the hygiene of the brain, and at the same time one of the most neglected and misunderstood. Moralists who have drawn their rules from their own inner consciousness, without being guided by the most elementary knowledge of the human body, have done much harm by decrying sleep, and teaching that it was virtuous to get out of bed after five or six hours' rest, while the brain was still muddled and the eyes refused to open. This is a great mistake—as great a one as the opposite lazy habit of lying snugged up in bed after waking, or while half awake. During sleep, it has been observed in cases where injuries to the skull allowed the brain to protrude, the organ becomes almost white, the blood leaving it as consciousness sinks

to rest. No definite time can be laid down for the night's rest of any and every person, inasmuch as it is a matter dependent upon constitution and habits. Eight hours is about the time required by most healthy adult persons; but some find that they need only six or seven hours. On the other hand, little babies sleep almost constantly, and children require more sleep than adults. In fine, the time needed for sleep is as much as can be spent in complete unconsciousness, and as enables the individual to rise from his pillow with bright eyes, a clear head, a decent temper, and good spirits—in other words, in health—neither self-indulgently wasting precious time in semi-unconsciousness, nor falling into the great mistake of supposing that to take less than enough sleep is a praiseworthy habit. Sleep is the food of the brain.

I shall give rather a long extract upon this point from the eminent "Mad Doctor," the late Forbes Winslow, because it is one upon which he spoke with authority:—

"There is no fact more clearly established in the physiology of man than this—that the brain expends itself and its energies during the hours of wakefulness, and that these are recuperated during sleep. If the recuperation does not equal the expenditure, the brain withers—this is insanity. Thus it is that in early English history people who were condemned to death by being prevented from sleeping always died raving maniacs; thus it is also that those who are starved to death become insane—the brain is not nourished, and they cannot sleep. The practical inferences are three:—First, those who think most, who do most brain-work, require most sleep. Second, time 'saved' from necessary sleep is infallibly destructive to mind, body, and estate. Third, give yourselves, your children, servants, all who are under you, the fullest amount of sleep they can take."

Mental overwork often takes the form of neglect of sleep; one who wishes to master a subject begrudges

himself a proper amount of rest. Many a man has broken down through making this mistake.

Another mistaken habit, and one which has to answer for many mental illnesses, is that of working without periods of intermission. Nearly all the organs of the body obey the law of alternate exercise and repose: they work, and then they rest. Of none is this more certainly the normal succession than it is of the brain. Churchhill truly wrote:—

> "*Constant* attention wears the active mind,
> Blots out our powers, and leaves a blank behind."

And Solomon as truly:—"Much study is a weariness to the flesh."

With wise attention to hygiene, however, and especially to the law of alternate exercise and repose, mental work is much more healthy than many mechanical occupations. Mr. Madden found that the average longevity of twenty distinguished natural philosophers was seventy-five years; of moral philosophers, seventy years; of religious authors, sixty-seven years; and of poets, who stand lowest on a long list, fifty-seven years.

The number of hours which may be allotted from the twenty-four to study, varies as much as the number required for sleep. Comparatively few persons can with any advantage work longer daily, month after month, at any deep and serious study, than Sir William Jones advised lawyers to do,

> "Six hours to law, to soothing slumber seven,
> Ten to the world allot, and all to heaven."

Neuralgia, a distressing disease of the nerves, is sometimes relieved by dieting the sufferer. Nerve-matter contains much fat. Dr. Anstie writes:—"It has several times occurred to me to see patients entirely lose neuralgic pains which had troubled them for a considerable time, after the adoption of a simple alteration in

their diet, by which the proportion of fatty ingredients in it was considerably increased." Fresh butter, cream, and cod-liver oil, may, therefore, be hopefully taken for neuralgia.

Alcohol acts more directly and more disastrously upon the brain than upon any other organ. It congests the brain with blood, and for the time greatly increases the mental activity; but its use is followed by extreme collapse. Spirituous liquors "alter the rate of going for a while, and at last spoil the machine." Those who use them to aid their working power are taking the first steps towards intellectual suicide. The habit once commenced is fatal, because it soon becomes impossible for the unfortunate victim to work without stimulus, and an increase of dose is required each time to produce the same effect. The only way to secure oneself against the ruin which has overtaken so many bright spirits, the slavery which has enthralled so many strong minds, the fall which has shattered so many nervous systems and destroyed so many careers, is to beware of the first steps upon the dangerous path.

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# CHAPTER XIV.

## THE MUSCLES AND THEIR WORK.

THE most ample provision is made for the protection of the several delicate vital organs described in the preceding chapters. The most easily injured, such as the brain and the lungs, are enclosed within a complete case of bone; and all are covered with masses of muscle, and padded about with fat.

But the bones and muscles have another office than this one of protection. They are the organs of motion and locomotion. By their action we move our limbs, or transport the entire body from one place to another. The bones form a system of levers, upon which the muscles act.

It must be noted that there are forms of vital movement not connected with the muscles. The changes in shape of the white corpuscles by their own inherent vital power have been already (p. 21) described. *Ciliary* motion is another and very interesting form of vital, but not muscular, movement.

Frequent reference has been made in previous chapters (especially in that on glands) to the tiny little bodies called *epithelium cells*, which line all the cavities of the body. Epithelium is divided into four classes, according to its shape; viz., *tesselated* (or pavement), *spheroidal* (or round), *cylindrical* (or column-like), and *ciliated.* The last-named variety has growing out of the top of each cell a number of minute filaments, like very

fine hairs (Fig. 27). These are called *cilia* (from the Latin word for the eye-lashes), and hence the epithelium upon which they appear is named ciliated, although in shape it generally resembles the cylindrical kind.

Now, when a piece of ciliated epithelium is taken from an animal that has not long been dead, and moistened, and then placed under the microscope, the

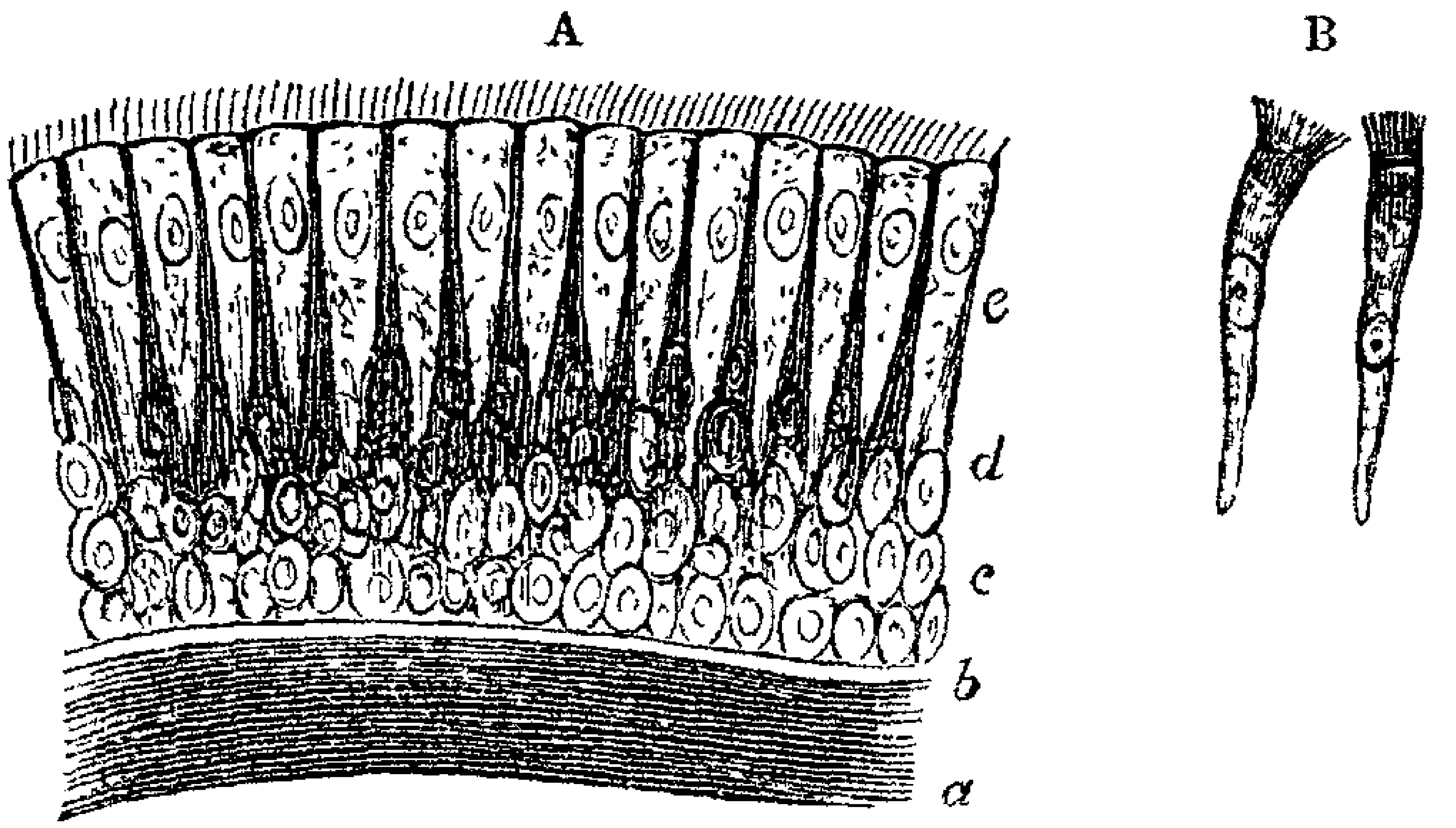


*Fig.* 27.—CILIA.*

A, portion of ciliated epithelium from the lungs, magnified 350 times. *a*, Elastic fibres of bronchial tube; *b*, basement membrane; *c*, deepest layer of cells; *d*, intermediate layer of cells, more elongated; *e*, fully developed cylindrical cells, with cilia along their tops. B shows two ciliated epithelial cells detached.

cilia are seen to be in a state of unceasing motion, waving backwards and forwards, and rising and falling like a field of corn beneath a gentle summer wind. The force with which they bend in one direction, however, is greater than that which they exercise in the opposite direction, as can be seen by placing a tiny bit of cork on one end of a piece of moist epithelium, when the waves of the cilia will pass the cork, by slow degrees, along to the other end. Thus, ciliated epithelium probably exists in the cavities in which it is found, to act as a kind of natural sweeper. This epithelium lines the whole of the

* From Kölliker.

mucous membrane of the respiratory tract, including the nose; it is found also in the ventricles of the brain. In the first of these situations its use is clear; its current, so to speak, runs outwards, and the passage of mucus or particles of dust, etc., towards the outside is thus facilitated. Perhaps, also, it aids in the gaseous interchange always going on in the lungs.

As to what really causes, or what circumstances control, the movements of the cilia, we have not the least knowledge. To say that it is a manifestation of vital force is only one way of confessing that we do not comprehend it; yet this is all we can say. But of how many facts is this true likewise! Man's knowledge of nature, great and full of interest as it is, is yet soon bounded by his ignorance. We are upon a little island of truth, surrounded by a quicksand of conjecture, and limited by an ocean of incomprehensibility. Year by year, science adds a portion of the quicksand to the dry land, and claims a little more space from beneath the dense waters; but still the ocean reaches far beyond, and still the difficulty of lowering its high-water mark becomes greater for every labourer, while in its depths not far from shore there probably rest marvels that no imagination has yet even suspected.

When we come to the consideration of any "ultimate fact" in nature, we cannot do anything but wonder and admire. It is no more a possibility to *finally* understand muscular movement than it is ciliary movement; but in the case of muscles, the difficulty is a step farther removed, because their action is controlled by the nervous system.

*Muscle* is that red firm substance which makes up the flesh of animals, the lean of meat. The bones are everywhere covered and the cavities are everywhere filled up by muscle, which gives to the form its roundness and beauty. The peculiar power of muscle has already been

several times mentioned. It is that of *contraction*; of becoming thicker, and shortening in proportion, under the influence of the nervous system. You will remember that it has been seen that all general movement, either of an organ or of the whole body, is the result of muscular contraction; and that some muscles are not under the control of the will, while others do obey the direct orders of the brain.

When the substance of muscle is divided as far as possible and examined with the microscope, there are found to be certain differences in minute structure between voluntary and involuntary muscles.

If an orange be cut through the centre, very little idea of its construction can be obtained by looking at it; and in just the same manner we are unable to see the beautiful structure of muscle in the meat which is cut at table. But if we peel an orange, and split it down the centre, we see that it is made up of a number of sections, each of which is enclosed in a fine skin; and if this envelope be stripped off, each section is found to be formed of numerous bundles of very delicate fibres, each bundle being fastened together by encasement in an exceedingly thin membrane. If you do not happen to remember all this, you should get an orange and inspect it. For a human being's muscles singularly resemble this arrangement of an orange. If a man were stripped of his outer skin, the muscles would be seen just as regularly disposed (though, of course, in a different form), and each one as cleanly enclosed in its own membranous sheath, as the segments of the orange.

Muscles are of various shapes, according to the position in which they are placed. In the limbs, they are mostly long, and more or less broad. Some are flat and spread out, some shaped like a pine-leaf or a fan, and some look exactly like a quill pen, with feathers

standing out from one or both sides. In every part the shape is most beautifully suitable for the purpose to be served.

When the enveloping sheath is taken off any muscle, it is seen that the muscle consists, like the segment of orange, of a number of bundles of fibres, each enclosed in a fine membrane. On further inspection, it is discovered that each of these large bundles is composed of a number of smaller bundles. These latter bundles are made up of *ultimate muscular fibres.*

Viewed under the microscope, these ultimate fibres are often seen to be marked by stripes running both round and along them. The fibres can be separated into fibrillæ in the course of the longitudinal markings, and into discs at the crossway stripes. Fibres which can be thus treated are under the control of the will. Involuntary fibres, such as those of the stomach and intestines, have no stripings, and will not break up into fibrillæ. The heart is the solitary exception to this rule; though its action is not voluntary, its fibres are faintly striated.

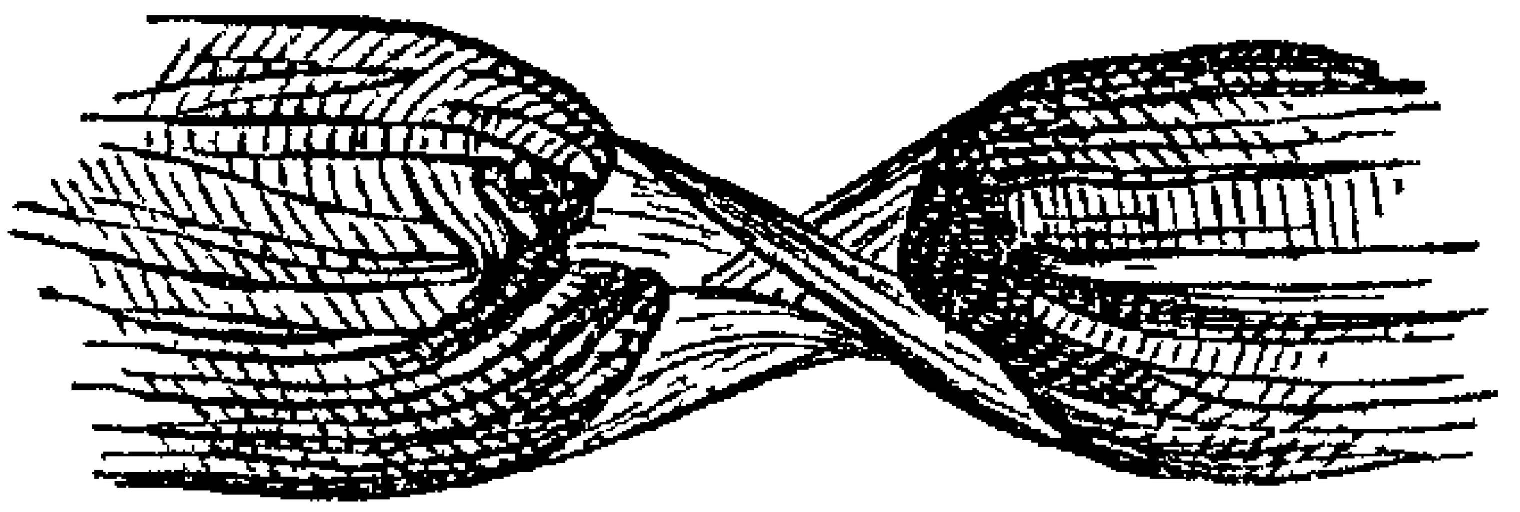

*Fig.* 28.*—Muscular fibres torn across; the enveloping sheath of membrane (the sarcolemma) remains untorn.

When a muscle contracts, every one of the ultimate fibres becomes thicker and shorter on its own account, and by the united action of them all under the control of the nerve-centres the general effect is produced.

Now, how are the muscles fastened to the bones? In the front of the wrist of a person who is not stout can be seen two slender cords. If one of these be traced up the arm, it can be felt to gradually flatten out into a thick soft mass—the muscle. These cords are the *tendons,* which extend from the muscles to the bones where the contracting power is to be fixed.

* From Tod and Bowman's *Physiology*, by kind permission.

You can readily see what happens when a muscle, attached by its tendon to a bone, becomes thicker and shorter. The shortening of the muscle necessarily pulls up the tendon, and this moves the bone. A little further explanation will be given after we have, in the next chapter, studied the joints and ligaments of the bones.

Voice and speech result from muscular action. At the top of the windpipe four cartilages of peculiar shape are so arranged as to form a kind of box. What is called "Adam's Apple" in the throat is really the projection of the largest of these cartilages. The proper name of the voice-box is the *larynx*.

Two fleshy bands, called the *vocal cords*, run across from side to side of the voice-box. While these hang slackly no sound is produced; this is why we breathe without making any noise. But when a number of muscles which are attached to the cartilages contract, so as to pull the vocal cords tense, and to stretch them exactly parallel with each other, then the air passing over them causes them to vibrate, and voice is produced. The higher the note, the more tense the vocal cords are drawn.

*Speech* is articulate sound; quite a different thing from voice. The so-called dumb animals have voice; but man alone has articulate speech. Words are formed by the aid of the tongue, teeth, and lips; some articulate sounds being chiefly pronounced by one of these parts, others by another. Thus, when the tongue is lost—as when it has been amputated for cancer—the power of speaking is only impaired, not lost; those letters, in the pronunciation of which the tip of the tongue is concerned, are turned into others, but the speech is still as intelligible as that of a little baby learning to talk.

*Exercise* is demanded for the health of the whole body, but of the muscles most of all. The red colour of muscles is chiefly caused by the great quantity of blood

circulating in them. Very large vessels send their branches into the muscles, and the capillaries are so arranged that the blood pours through them with especial readiness.

This great blood-supply is furnished to the muscles on the assumption that they will be properly used. When they remain inactive they do not require—indeed they cannot use—this quantity of blood. Instead of its oxygen being burnt up, and its other life-giving elements drawn out to supply the waste of substance which always results from work, only a small portion of the blood is used by a lazy muscle. The internal organs, which are always more or less constantly at work, attract this surplus blood to them by their activity, and become congested and overloaded with it. One room of the house is kept shut up, and, since there are people enough to comfortably fill the whole, the other rooms must be unhealthily and unpleasantly crowded.

In this way neglect of muscular exercise directly injures the whole of the body. It does this also by depriving the various organs of the stimulus that they should receive from general movement. The skin and the lungs act much more freely and readily during and after exercise. The circulation is aided too. Not only does the heart act more energetically, but the pressure of the muscles upon the veins directly assists the progress of the blood.

The necessity of exercise for the health of the muscles themselves is more obvious, and better appreciated by everybody. We all know that muscles which are much used are greatly increased in size and strength thereby. The blacksmith has "muscles in his brawny arms, as strong as iron bands." Trumpeters have the *buccinator* muscle in the cheek, which they use in blowing, much larger than other people. These instances are typical of the whole body. All the muscles

of indolent persons, or those who follow sedentary occupations, are soft and flabby. When such muscle is examined under the microscope, it is found to have undergone more or less change of structure; the fibres have become irregular and indistinct, tending to the entire loss of their special power, and to degeneration of the tissue into fat. On the other hand, when the body has been actively employed, the muscular structure is well defined, and every muscle is firm, red, and well shaped.

These scientific facts give the reason why a certain amount of bodily exertion is essential to health. Brisk and energetic walking sets in motion a great number of muscles, and is an excellent form of exercise. It is well when those who have to sit in workrooms and offices all day have their homes so situated that they *must* walk for a quarter of an hour or more night and morning. A short brisk walk will be more beneficial than a long languid one. Dumb-bell and other indoor gymnastic exercises are good; but they are not equal in value to games played in the open air.

Growing muscles especially demand use for their healthy development. Schoolboys commonly get quite exercise enough; but girls do not, and no reform is so much needed in their education as the introduction of regular physical training. Girls need strengthening for their duties in after-life every whit as much as boys. "We need," as Dr. Elizabeth Blackwell writes, "strong arms that can cradle a healthy child, and hold it crowing in the air; backs that will not break under the burden of household cares; a frame that is not exhausted and weakened by the round of daily duties." To secure this necessary robust health, proper training of the muscles by vigorous use is required. Girls at boarding-schools should be encouraged to play lawn-tennis, and other games involving running. The fact that their exercise is often confined to a doleful walk in procession, and a stroll

round the paths of a garden, must be held to account for much ill-health among grown women.

In connection with this subject of neglect of health in education, another point may be mentioned. There is a deformity to which the inhabitants of hilly towns are especially subject, and which consists in a loss of the arched form of the foot, so that the elasticity of the gait disappears, and the body jolts with every step. Mr. Skey says:—"I saw the daughter of a gentleman who had just returned from a finishing school. This deformity had made some progress in both feet. Without making any other inquiry, I said, 'I congratulate you on having obtained the prize at school for dancing.' She looked up in surprise, and inquired how I had obtained knowledge of the fact. The main fact I knew from the form of the foot." This deformity is not the result of the dancing, which is, in itself, a healthful exercise. It results from the excessive "turning out the toes" which the dancing-master requires. "Nature designed the foot to be so far only everted from its fellow that the toes might be kept from collision in the act of walking; but the dancing-master, more learned in his vocation, requires this angle to be largely increased, and the consequence is that we observe in all students of this noble art a distortion of the foot proportioned to their observance of its rules."

Such a fact as this suggests the desirability of gymnastic exercises being carried on upon definite scientific principles. To be really useful, drill movements must be founded upon physiology. If muscles and ligaments are twisted or strained in the wrong direction, they will be injured instead of benefited. A complete system of gymnastics, intended to put in use and make obedient to the will every voluntary muscle of the body, has been designed by a Swedish gentleman named Ling, and adopted in the schools of his country.

A word of caution is necessary against over-exercise. Professional trainers know that when men are very anxious to win in some athletic contest, there is great danger that they will overdo themselves in preparation for it. A certain amount of exercise, the proper quantity varying for different individuals, must be taken every day. But if the proper limit of such exertion is exceeded, the man grows daily weaker, instead of stronger. He "trains off," as it is called. The muscles can be *gradually* brought to bear great fatigue; but to suddenly commence violent and long-continued physical exercises is highly injudicious. For example, it is very unwise for any one who is not in the habit of walking long distances to go upon a pedestrian tour for his holiday with the intention of covering as much ground daily as he possibly can; he should confine himself to distances which he can accomplish without great fatigue. Error in this respect will probably produce physical exhaustion which will more than counterbalance the gain from a full supply of ozone, change of scene, and freedom from business routine.

*Sprain* consists of a stretching, or perhaps partial tearing, of a tendon or ligament. Perfect rest is the treatment for it. If there is swelling and puffiness, with great tenderness, a cold-water bandage may be applied, after the part has been gently rubbed with tincture of arnica. This tincture (which is not, as often supposed, an homœopathic drug only, but is in the pharmacopœia, and may be bought from any good chemist's shop) appears to have a peculiarly sedative effect upon injured muscular tissue, and may be applied to bruises also with advantage.

# CHAPTER XV.

## THE BONY FRAMEWORK.

We have now to consider the bones—which form, as it were, the foundation upon which the structure of the body is erected—both in their relation to the soft parts, and as a system of levers.

Bone is composed of gelatine, hardened by earthy salts—lime, magnesia, and soda. The lime can be dissolved out of a bone by laying it for a considerable time in a mixture of two ounces of spirits of salt and two-thirds of a pint of water. The bone thus becomes so soft that it can be twisted in any manner. The old cottage ornament of an egg in a narrow-mouthed bottle was prepared in this way; the egg-shell becomes soft and flexible, just as the bones do, when the lime is removed by the action of the acid.

In adults, gelatine forms one-fourth of bone; in children it composes one-half, and in old people only one-eighth. The consequence of this excess of earthy matter in old people is that the bones become brittle and easily break; while it results from the deficiency of the salts in children that their bones are weak, and a fracture to them is of comparatively small importance, mending very readily. This natural softness of the bone, however, makes children very liable to deformity if they are kept in cramped positions, or put to work too early. Half a century ago, before the first Factory Act was made by Parliament, infants of six and seven years

of age were compelled to work in the mills for sixteen hours a day; and the soft bones of these poor little creatures, for whom Mrs. Browning wrote "The Cry of the Children," were distorted in the most terrible manner. A similar evil may be produced by putting babies upon their feet too early. When young children are not given good food, or when either digestion is imperfect, or the absorption of the chyle is prevented by scrofula or other causes, the bones become very soft, and bend, because there is not enough lime supplied to them by the blood. This is the disease called *rickets*.

The minute structure of bone, as seen under the microscope, is very beautiful. The large spaces seen in Fig. 29 A are shown in B to be small branching and interlacing canals. These are the *Haversian canals*, and in them blood-vessels run through the bone. The outer surface of bone is covered by a tough membrane, called the *periosteum*. The Haversian canals all open, sooner or later, upon the surface of the bone, and the periosteum descends into their openings, while the blood-vessels of bone and membrane become continuous. The other ends of the canals open into the marrow which runs down the centre of hollow bones.

The dark patches arranged in rings around each Haversian canal are spaces, called *lacunæ;* and the fine lines running between these are exceedingly minute tubes, called *canaliculi*, through which one lacuna is placed in communication with another. By means of this delicate arrangement the blood permeates the whole of the firm tissue of bone, and nutriment is carried on.

There are about two hundred distinct bones in the human body. The number is greater in children than in adults, because many bones which are separate to permit growth in childhood consolidate, or join to make one, when the full size is attained. For instance, the backbone is at first composed of thirty-three distinct

small bones, called *vertebræ*. In adults, only the top twenty-four of these remain separate; the rest unite into a solid mass.

Twenty-four ribs—twelve on each side—run round

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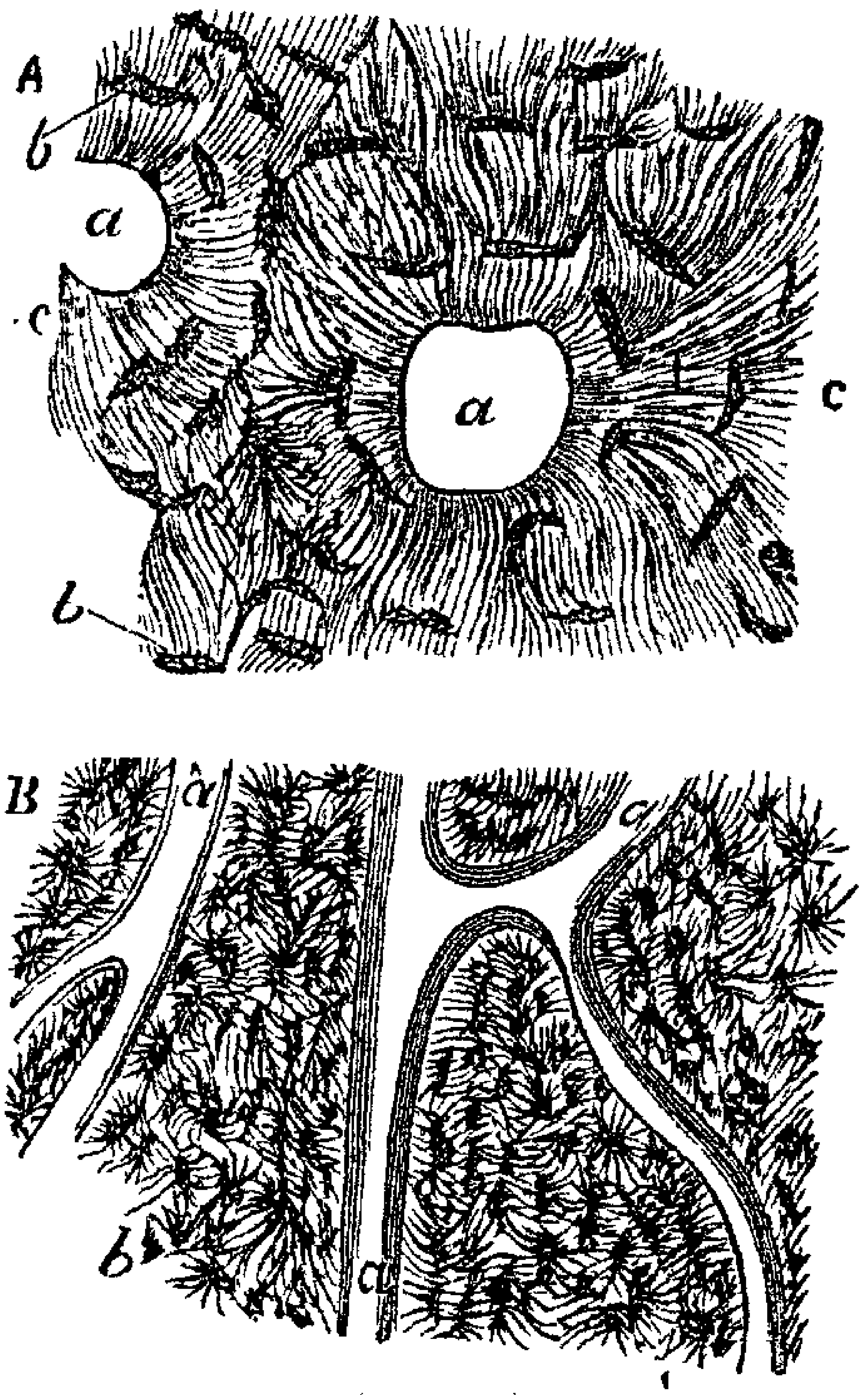


*Fig.* 29.*

A, a transverse section of bone, magnified 250 diameters; *a*, Haversian canals; *b*, Lacunæ; *c*, Canaliculi. B, longitudinal section of bone, magnified about one hundred times. References as in A.

from the vertebral column to the breast-bone, or *sternum*. The top seven are called the *true ribs*, and are fastened directly on to the sternum itself. The remaining five are the *false ribs*, the upper three of which are attached to the end of the seventh rib by a piece of cartilage (or gristle), while the last two are left quite free in front, and called the *floating ribs*.

* After Kölliker (reduced).

The shoulder-blade rests upon the ribs behind, and the collar-bone arches above them, with its one end fastened to the breast-bone, and its other to the shoulder-blade, upon which, likewise, the top bone of the arm is fastened. The anatomical name of the shoulder-blade is the *scapula*, and that of the collar-bone, the *clavicle*.

At the bottom of the spine the hip-bone and some others are so joined together as to form the basin, or *pelvis*.

There is one long bone (*femur*, or thigh-bone) in the top of the leg, and two (the *tibia* and the *fibula*) from the knee to the foot. Three bones similarly arranged (the top one being called the *humerus*, and the lower two, the *radius* and the *ulna* respectively) form the arm. The wrist-bones (or *carpus*) are eight in number, and there are seven corresponding (*tarsal*) bones in the foot. The finger-bones receive the same anatomical name (*phalanges*) as the toe-bones. The palm of the hand contains the *metacarpal* bones, and the centre of the foot, the *metatarsus*.

The skull is composed of eight principal bones firmly jointed together. Those who have a little baby at home can verify for themselves what was just said here about the separation in children between bones which are solid in adults. If they feel the baby's head very gently and tenderly, they will find that along the middle, where the parting is made in a girl's hair, there are the jagged edges of two bones, as well as a soft space under which no bone at all can be felt. This provision enables the bone to grow; when the baby's head has got nearly broad enough, the saw-like edges will fit into one another, and become solidly joined. Until this happens, of course the head must be treated with great gentleness.

The bones are fastened together by *cartilage*, or gristle. Where two bones are attached to each other is called a joint, or *articulation*.

Joints may all be classed as either *perfect* or *imperfect*. The latter are those in which the bones are connected together by plates of cartilage, and have only so much movement as the flexibility of the joining substance will permit. For example, the vertebræ which make up the spine are separated one from another by thick plates of elastic cartilage, which give springiness and mobility to the column, but do not admit of much movement between the individual bones. The elasticity of these plates of cartilage is so great, however, that we are actually about half an inch shorter when we go to bed than we were when we got up in the morning, by reason of their flattening out under the weight of the erect position.

Perfect joints are those which have smooth surfaces to play upon each other. These are of three kinds. There are *ball-and-socket* joints, in which the round head of one bone fits into a cup hollowed out for it in the other; the shoulder and the hip are instances of this form. Then there are *hinge-joints*, resembling, in the way in which they move, the hinge of an ordinary door; the elbow is articulated after this fashion. Finally, there are *pivot joints*, in which the one bone works round a peg furnished by the other; the head turns upon the spine by means of this arrangement.

In perfect joints the two bones are held together by tough, strong, fibrous bands; these are the *ligaments*. Further, in all joints of this class, the surfaces which touch each other are covered by a layer of cartilage: and lining that cartilage, so as to interpose between the bones, is a fine membrane, called *synovial membrane*, because it secretes a fluid to which the name of *synovia* is given, and which serves to lubricate, or oil, the joint.

The bones thus fastened to each other move upon one another according to definite mechanical principles; they form, in conjunction with the muscles, a system of

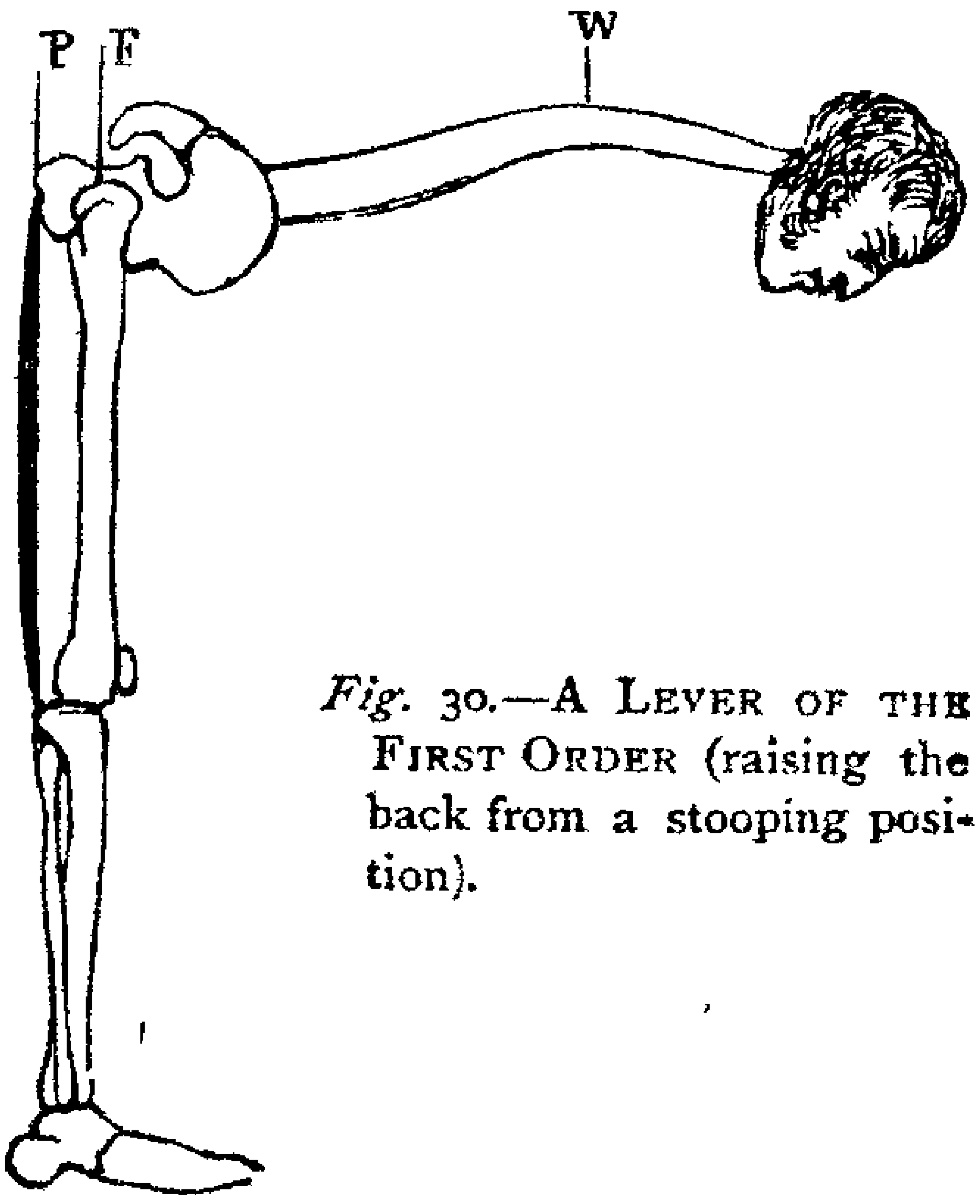


*Fig.* 30.—A LEVER OF THE FIRST ORDER (raising the back from a stooping position).

levers in the body. A lever is made by a rigid bar (such as a long bone) with some part of it fixed (as the joint fixes part of a bone), a weight to be moved at some other point, and a power to be applied at a third place (the muscles being the power in the body) by which the weight or resistance is moved upon the support given by the fixed point. Thus, in stirring the fire, a lever is brought into play. The poker is fixed on the bar, one of its ends is placed under the coal that is to be lifted, and the hand of the fire-mender applies force at the other end. The fixed point is called the *fulcrum;* that which has to be moved is the *weight* or *resistance;* and the moving force is the *power.* Mechanicians recognise three orders of levers, according to the relative positions of the power, fulcrum, and weight, as follows :—

*Fig.* 31.—A LEVER OF THE FIRST ORDER.

Order 1. W. F. P.
" 2. F. W. P.
" 3. F. P. W.

Poking the fire, as described above, is an instance of a lever of the *first* order—*i.e.* where the fulcrum is between the power and the weight; an instance of this

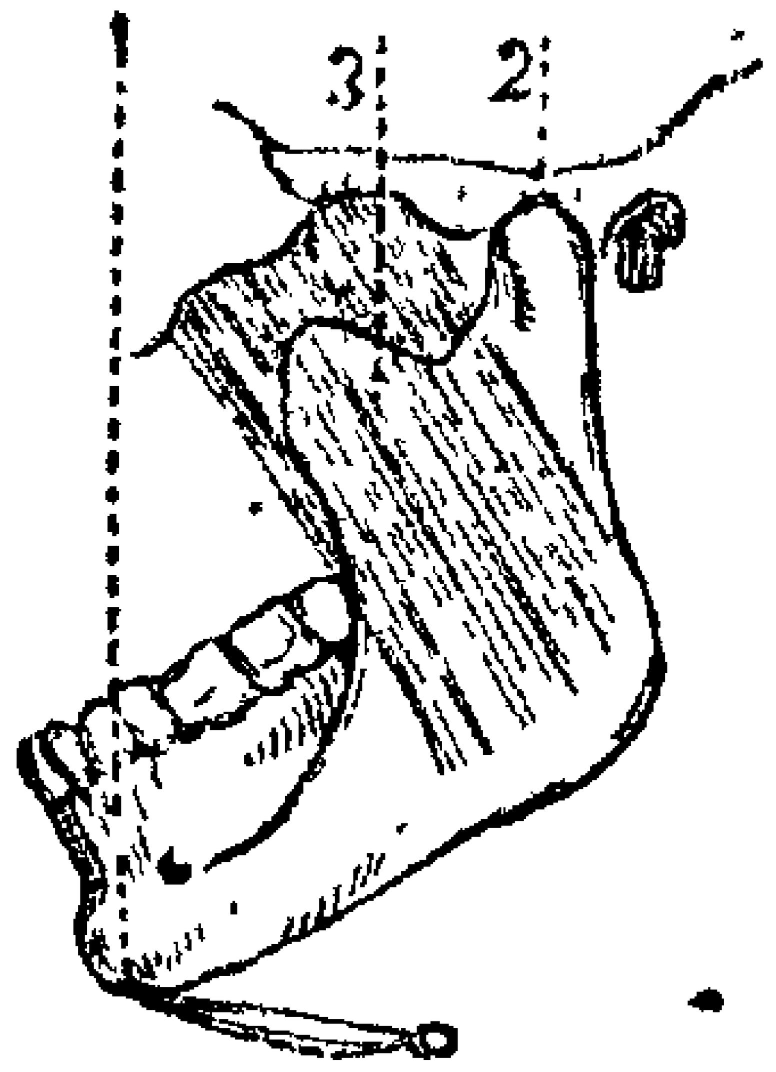


*Fig.* 32.—A Lever of the Second Order.
1, power; 2, fulcrum; 3, resistance.

*Fig.* 33. F

in the human body is raising the trunk to the erect posture, after stooping from the hips.

Lifting the handles of a wheel-barrow is an example of a lever of the *second* order, in which the power is at one end, the fixed point at the other, and the weight between. In the body, opening the mouth by pulling down the lower jaw, is an illustration of the second order of levers (Figs. 32 and 33).

When a washerwoman lifts a prop away from the line, she generally exhibits the action of a lever of a third order; the fulcrum being the point which rests upon the ground, the weight the top of the prop, and

the hand which grasps between these places the power. In the body, lifting the hand up to the shoulder is an illustration of the third order of levers.

*Fig.* 34.—A LEVER OF THE THIRD ORDER.

*Dislocation*, or, as it is called in common language, "putting the joint out," is among the most common of accidents. Dislocation consists in pushing one bone of an articulation away from its union with the other. In the case of the larger joints, such as the hips, the difficulty of "reducing" a dislocation is enormous, owing to the force with which the great muscles attached to the bone contract when an attempt is made to pull it back into its proper place. The practical point, and the reason for which I mention the subject here, is that the longer a dislocation is allowed to remain unreduced the more difficult it becomes to treat. Fibrous adhesions form around the misplaced end of the bone, fixing it out of position. Therefore, even a finger joint "put out," and still more, one of the larger joints, as the elbow, should be seen by a good surgeon without a day's delay.

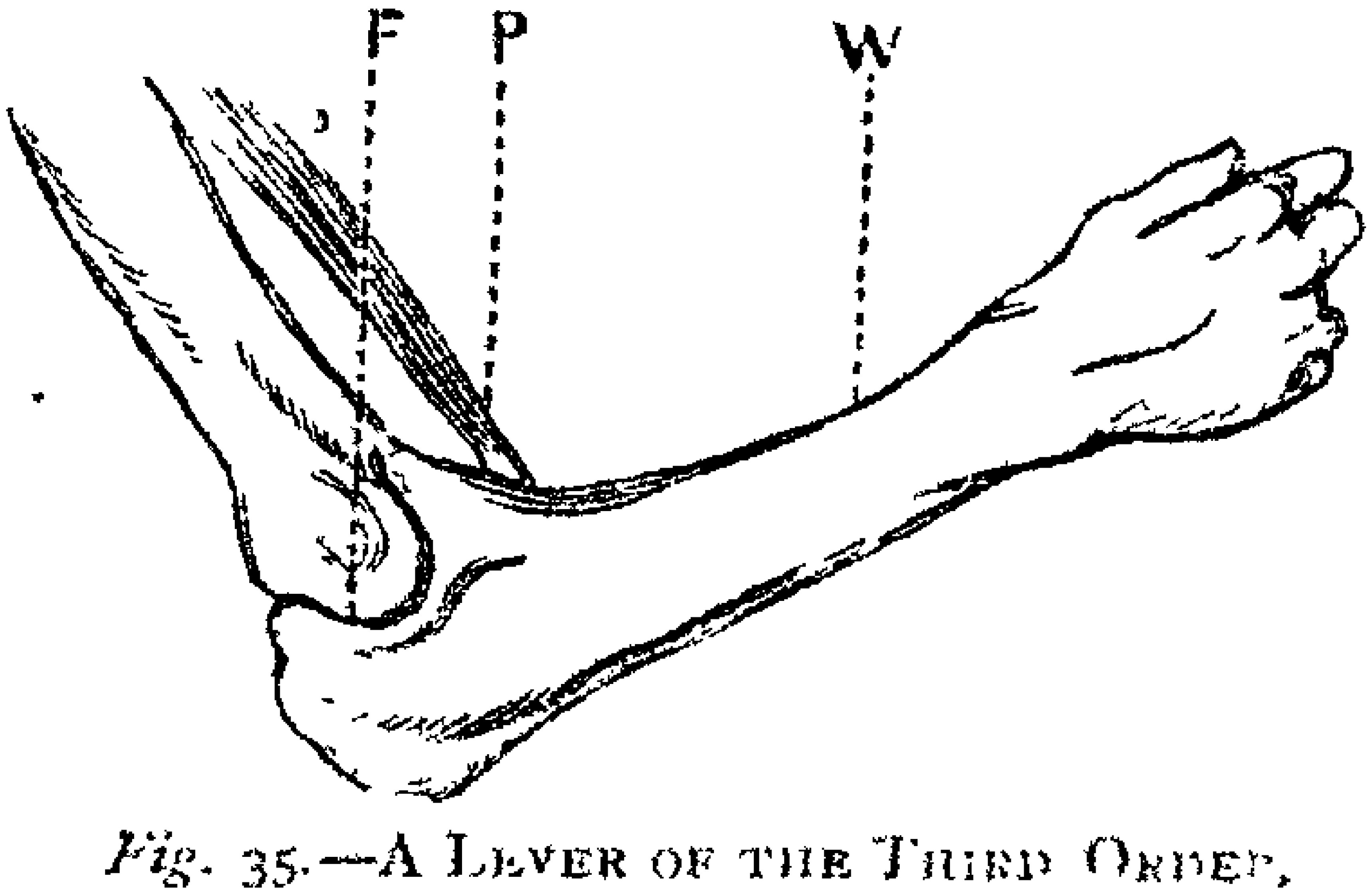

*Fig.* 35.—A LEVER OF THE THIRD ORDER.

*Fracture* is breaking of the bone. The great point

to be looked to in the removal of a person who has sustained a fracture is that he be lifted about so carefully as not to force the bone through the skin. The jagged ends of the broken bone are easily pushed through the flesh by incautious handling, and this occurrence greatly increases the seriousness of the accident.

The structure of the bony foundation of the trunk shows the danger of compression of the waist. Tight belts, strings, or stays must necessarily press upon and injure the delicate, soft organs of the abdomen. Stays in themselves, if neither long nor thickly whaleboned, are not only harmless, but even useful, so long as women's garments continue unwisely to be made to depend upon the hips instead of from the shoulders; but if they are too stiff to bend with the figure, or too tightly laced to allow the most perfect freedom of movement, they become highly mischievous. The reason for this is plain to any one who has so much acquaintance with anatomy as my readers will have gained. And surely it is scarcely possible that a girl who knows that the lower ribs, being floating, are very readily compressible, and that the most delicate soft organs of the body are beneath so closely packed that pressure must squeeze them together, and push them out of place upon one another, can be guilty of deliberately injuring herself in such a manner, sacrificing a long life of womanly happiness to a few fleeting years of mistaken girlish vanity.

Upon this point, as upon every other, the practice which must be followed to retain health is dictated by the facts of physiology. The very architecture shows the care required for the preservation of each apartment; if, through ignorance or heedlessness, we neglect the indications thus supplied, upon us must the punishment fall in the premature decay and ruin of the House of Life.

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# INDEX.

*All scientific words which the general reader might be doubtful how to pronounce, have the pronunciation here indicated, either by accent marks or by spelling according to sound.*


ABDOMEN, 5, 6.
Absorption, 54.
Accidents to blood-vessels, 45.
  to bones, 179
"Adam's apple," 167.
Afferent nerves, 150.
Air-cells, 10.
Air, composition of, 30.
  difference between expired and fresh, 31, 40.
  tidal, 15.
  reserve, 15.
  residual, 16.
  stationary, 16.
Alcohol, 39, 77-80, 94, 161.
Albumen, 62.
Ammonia, 60.
Ampullæ (am-pul'-e), 130.
Am'yloids, 64.
Analysis of animal body, 60.
  air, 30.
Anatomy, 6.
Animal food, 63, 68, 69.
ANSTIE, Dr., quoted, 160.
Aorta (a-or'-ter), 18.
Appetite, loss of, 95.
Apex of the heart, 17.
A'queous humour, 112, 115.
Arachnoid (ar-ack'-noid), 140.
Arbor vitæ, 143.
Arnica, tincture of, 171.
Arteries, 18, 20, 45.
  aorta, 18.
  pulmonary, 24.
  hepatic, 90.
  renal, 101.
  in the villi, 56.
Articulations, 175, 176.
Ashes of body, 60.
Asphyxia, 37.
Auditory nerve, 132, 147.
Auricles (awe'-rik kels), 18.
Auriculo-ventricular apertures, 24.
  valves, 25.
BACKBONE, 174.
Ball-and-socket joints, 176.
Baths, 108.
Beverages, 73, 76.
Bile, 55, 85.
  office of the, 56.
  secretion of, 89, 92.
"Bilious attacks," 94.
Black hole of Calcutta, 38.
BLACKWELL, Dr. Elizabeth, quoted, 158, 169.
Bladder, gall, 90.
  urinary, 99.
Blood, 21.
  coagulation of, 21.
  different tint in arteries and veins, 22.
  reasons for this difference, 32.
  changes in while in the lungs, 34.
  changes in while in the capillaries, 35.
  supply to muscles, 168.
  supply to bones, 173.
Blood-vessels, 9, 18.
Bone, structure of, 172.
Bones, 162, 172-180.
  small, of the ear, 128.
  broken, 170.
BOWMAN, Mr., 102.
Brain, 137, 142-161.
  base of the, 144.
  coverings of, 140.
  overwork of the, 159, 160.
  weight in relation to mental power, 159, 160.
Bread, 71.
Breathing, 11
Bronchial tubes, 10.
BUDD, Dr., quoted, 94.
Burning, chemistry of, 36.

CAFFEINE, 77.
Calcutta, Black Hole of, 38.
Calico, 110.

Canaliculi, 173.
Capillaries (cap'-il-la-rees), 18, 20, 101.
Carbon, 35, 60, 63, 66.
Carbonic acid, 30, 32, 35, 37, 45, 60, 99.
CARPENTER, Dr., quoted, 155.
Carpus, 175.
Cartilage, 9, 14, 175.
Casein, 63.
Cells, epithelial, 87, 162.
  liver, 92.
  nerve, 140.
Cerebro-spinal nervous system, 138, 139-155.
Cerebellum (sĕr'-e-bel'-lum), 142, 143, 153.
Cerebrum (sĕr'-e-brum), 142, 144-146, 153.
Choroid (kor'-oid), 112, 114.
CHURCHILL quoted, 160.
Chyle, 56, 58.
Chyme, 54, 64.
Ciliary motion, 162, 163.
  muscle, 116.
  processes, 114, 116.
Circulation of the blood, 17-29.
  review of the, 29.
  rapidity of the, 29.
Circulation of matter, 62.
Cisterns, 75.
Classification of food stuffs, 62.
Clavicle, 175.
Clothing, 110.
Coagulation of blood, 21.
Cochlea (kok'-lear), 129, 131, 133.
Cocoa, 76.
Coffee, 76.
Combustion in the body, 36, 38.
Concha (kon'-ka), 125.
Conjunctiva, 124.
Consciousness, 153.
Consumption, 40, 44.
Convolutions of cerebrum, 146, 154.
Cooking, 83.
Cornea, 112, 114.
Corpuscles of blood, 21.
  of nerve, 162.
Corpus callosum, 145.
  striatum, 144.
CRABBE quoted, 96.
Cream, 71.
CRITCHETT, Mr., quoted, 125.
Crystalline lens, 112, 116, 121.
Crura cerebri, 144.

DANCING, 170.
Deafness, 134.
Death from neglect of hygienic laws, 1, 38, 39, 108, 111.
Decussation of anterior pyramids, 152.
Derma, 103, 105.
Diabetes, 148.
Diaphragm (di'-a-fram), 5, 13, 15, 52, 89.
DICKENS quoted, 51.
Digestibility of food, 80-82.
Digestion, organs of, 47-59.
  in the stomach, 54.
  in intestines, 55.
  office of bile in, 56.
    of pancreatic juice, 56.
  review of the mechanism of, 58, 59.
Dislocation, 179.
Drum of the ear, 126.
DRYSDALE, Dr. C. R., quoted, 45.
Ductless glands, 97.
Duodenum (du-o'-dee-num), 55, 89.
Dura mater, 140.
Dust-bins, 44.

EAR, structure of, 125-132.
  bones, 128.
  dust, 130.
  foreign bodies in the, 126.
  windows of the, 128.
Education, 157, 170.
Efferent nerves, 150.
Eggs, 62, 66.
Elastic tissue, 20.
Enamel, 48.
Endocardium (end'-o-card'-e-um), 25.
Endolymph, 130.
Epidermis, 103, 104, 109.
Epiglottis, 50.
Epithe'lium, 87, 100, 162, 163.
Eruptions, 110.
Eustachian tube (use-tay'-ke-an), 50, 127.
Excretion, 85, 98, 107.
Exercise, 39, 95, 167.
Expiration, 12.
Eye, structure of the, 112-123.
  ball, 113.
  adjustment of the, 121.
  appendages of the, 124.
  waters, 123.

FAT, 56, 63, 140, 160.
Fatness, excessive, 84.
Femur, 175.
Fenestra ovalis, 128, 132.
  rotunda, 128, 132.
Fibres of Corti, 132, 133.
  nerve, 140.
  ultimate muscular, 166.
Fibrin, 62.
Fibula, 175.
Filters, 76.
Flannel, 110.
Flesh-formers, 62.
Food, animal, 63.
  classes of, 62.
  digestibility of various, 80.
  how swallowed, 49.
  peculiar, 67.
  vegetable, 80.
Fracture, 179.
Fruits, 68.

GALL-BLADDER, 90.
Ganglia of nerves, 139, 142.
Gases, 31, 33, 34. See *Oxygen, Carbonic acid*, etc.
 law of the diffusion of, 35.
Gastric juice, 53, 54.
Gaswork, the living body a, 36.
Gelatine, 63.
Girls, physical exercise in schools for, 169.
Glands, structure of, 86-88.
 ductless, 97.
 gastric, 53.
 lachrymal, 124.
 lymphatic, 57.
 salivary, 49.
 sweat, 106.
Glomerulus, 101.
Glosso-pharyngeal nerve (glos-so'-fārē-in'-ge-al), 147.
Glottis, 50.
Gluten, 62.
Glycogen, 93.
Greenland, diet of. 67.
Grey nerve matter, 141, 142, 147.
Gullet. See *Œsophagus*.
Gymnastics, 170.

HAVERSIAN canals, 173.
Heat, animal, 36.
Heat-producing foods, 63, 64.
Hearing, 133.
Heart, 7, 17, 23, 25.
Hepatic artery, 88, 90, 92.
 veins, 93.
 duct, 88, 90, 92.
Hinge-joints, 176.
Horse, situation for the, 44.
Humerus (hew'-mer-us), 175.
HUXLEY, Professor, quoted, 125, 153.
Hydrochloric acid, 53.
Hydrogen, 60.
Hygiene (hy'-gee-ane), 6.
Hysteria, 39.

INCUS, 128.
Indigestion, 53, 81.
Infectious diseases, 110.
Inorganic, 4, 61.
Inspiration, 12.
Intercostal muscles, 14.
Internal ear, 129-132.
Intestines, 6, 55, 56.
Iris, 112, 114.

JAUNDICE, 92.
JOHNSTONE, Professor, quoted, 77.
Joints, 176.
JONES, Sir W., quoted, 160.

KIDNEYS, 6, 98-102.
 pelvis of the, 99
 pyramids of the, 100.
Kidney complaints, 108.
Kreatin, 68.

LABYRINTH of ear, 129.
Lachrymal duct (lak'-rim-mal), 124.
 gland, 124.
Lacteals, 58.
Lacunæ, 173.
Larynx (lar'-rinx), 167.
Layer of rods and cones, 117-119.
Law of nature, 35.
Lead in water, 76.
 absorbed by cutis, 104.
Lens, crystalline, 120.
Levers, 177-179.
Ligaments, 176.
Light, 120.
Linen, 110.
Liver, 6, 89-93.
 "complaint," 94.
 pills, 95.
Liquor sanguinis (like'-wor sang-wi-nis), 21.
*Londonderry, The*, 38.
Longevity of brain-workers, 160.
Long-sightedness, 122.
Lungs, 7-12.
 quantity of air contained in, 16.
 blood-vessels in, 24.
 changes in air in, 33.
 as excreting organs, 98.
Lymphatic system (lim-fat'ic), 57, 58.

MACULA lutea, 118.
MADDEN, Mr., quoted, 160.
Malleus (mal'-le-us), 128.
Malpighian capsule, 100.
MAPOTHER, Dr., quoted, 107.
Marsh gas, 44.
Measle-worm, 69.
Meat, 68.
Medulla oblongata, 142, 148, 152.
Membranes, 9, 33, 56, 87, 176.
Memory, 155.
Mercury, 95, 104.
Metacarpal bones, 175.
Metatarsal bones, 175.
Middle ear, 126.
Milk, 71.
Mitral valve, 25.
Modiolus, 131.
Motor nerves, 150.
Mucous membrane, 56
Muscles, 162, 164, 171.
 abdominal, 14.
 blood-vessels of, 168.
 force of the respiratory, 16.
 involuntary, 23, 115, 138, 166.
 intercostal, 14.
 of eyeball, 124.
 papillary, 26.
Muscular tissue, 13, 166.
 fibres, 53, 98, 115.

NERVE cells, 140.
 centres, 140.

Nerve fibres, 140.
force, 151.
plexuses, 139.
Nerves, the auditory, 132, 147.
the cerebral, 146, 148.
the olfactory, 136, 146.
the optic, 117, 147.
spinal, 142, 149, 150.
sympathetic, 139.
Nervous action, reflex, 152.
Nervous system, cerebro-spinal, 139.
sympathetic, 138.
"Nervousness," 39.
Neuralgia, 160.
Nitrogen, 30, 59, 66.
Nitrogenous food-stuffs, 62, 65.
Nose, 135.

OATMEAL, 69.
Obesity, 84.
Œsophagus (e-sof'-a-gus), 50, 51, 53.
Olfactory nerve, 136, 145.
Optic nerve, 117-119, 146.
Optic thalami, 144, 147.
Organ, 4.
Organic, organised, 4, 61.
Organic matter in water, 75.
Osmosis, 55, 64.
Over-eating, 95.
Over-exercise, physical, 171.
Over-work, mental, 159, 160.
Oxygen, 30, 60.

PAINTING the face, 111.
Palate, soft, 50.
hard, 136.
Pancreas, 6, 55, 89, 96.
Papillæ of skin, 105, 134.
tongue, 49, 135.
Papillary muscles, 26.
PARKES, Dr., experiment by, 77.
Parsnips, 70.
Peas, 69.
Pelvis, 5, 175.
of the kidney, 99.
Pepsin, 53.
Pericardium, 17.
Perilymph, 130.
Periosteum, 173.
Peritoneum, 8.
Perspiration, 106.
Phalanges (falan'-gees), 175.
Pharynx (far-rinx), 49.
Phosphorus, 140, 141.
Physiology, 6.
Pia mater, 140.
Pills, prescription for liver, 95.
quack, 71, 96.
Pigment layer of skin, 106.
cells of eye, 114.
Pineal gland, 144.
Pituitary body, 144.
Pivot joints, 176.
Pneumogastric nerve (new'-mo-gas'-trick), 147.
Plasma, 21.
Pleura (plu'-rah [sing.] plu-ree [plu.], 7.
Plexus, nervous, 139.
Pons Varolii (ponz var-o-lee-i), 144.
Potatoes, 70.
Potash, 70.
Portal vein, 90, 92.
Preventible disease, 1.
Proteids (pro-tee-ids), 63.
PROUT, Dr., quoted, 94.
Public Health Act, 43.
Pulmonary artery, 24, 26.
veins, 26, 28.
Pylorus (py-lore'-us), 55.
Pyramids of kidney, 99.

QUACK medicines, 96.

RADIUS, 175.
Rain-water for drinking, 74.
Reaction after bathing, 109.
Reflex nervous action, 152.
Renal artery, 101.
vein, 102.
Respiration, 7-12.
organs of, 7.
an involuntary action, 12.
mechanism of, 13.
number per minute of, 15.
Respiratory muscles (strength of), 16.
Retina, 112, 116, 117.
Rickets, 173.
Ribs, 14, 174.
RUSKIN, John, quoted, 159.

SACCULE, the, 130.
Saliva, 49, 64.
Salivary glands, 49.
Salts in the body, 60, 64, 70.
Sarcolemma, 166.
Scalæ of the ear (ska'-lee), 132.
Scapula, 175.
Scarf-skin. See *Epidermis*.
Sclerotic (skler'-ot-ic), 112, 113.
Scurvy, 69.
Secretion, 85.
Seeing, 120.
Semicircular canals, 129, 133.
Semilunar valves, 28.
Sensation, 150, 152.
Sensory nerves, 151.
Serous membranes, 9, 17.
Serum, 9.
of the blood, 21.
Sewers, defective, 44, 75.
Short-sightedness, 122.
Sight, 120.
Skin, the, 102, 109.
constitutional effects of dirt upon the, 107.

Skin, eruptions on the, 110.
SKEY, Mr. quoted, 170.
Skull, 140, 175.
Sleep, 158, 159.
Smelling, 136.
Soap, 109.
SOLOMON, 160.
Sound, 132.
Soup for the sick, 83.
Spectacles, 122.
Speech, 6, 97.
Spine, 174.
Spinal cord, 139, 141.
  nerves, 142, 149, 150.
Spiral canal, 131.
Spleen, 6, 97.
Split peas, 69.
Sprain, 171.
Squinting, 124.
Stapes (sta′-pees), 129.
Starchy foods, 40, 56, 64.
States of consciousness, 154.
Stays, 180.
Sternum, 174.
Stomach, 50, 52, 53, 81, 82.
Suffocation, 38.
Study, daily amount of, 160.
Supra renal capsules, 97.
Sweat, composition of, 107.
  glands, 106.
Swallowing, 50.
SYDNEY SMITH quoted, 94.
Sympathetic nerves, 138, 139.
Synovial membrane, 176.
Systemic circulation, 29.

TAPE WORM, 69.
Tarsus, 175.
Taste, 34, 35, 49, 135.
Tea, 75, 77.
Teeth, 47, 48.
Temperature, body, 26.
Tendons, 166.
Theine, 76.
Thoracic duct (tho ras′-ik), 57.
Thorax, 5, 7.
Thymus, 97.
Thyroid, 97.
Tibia, 175.
Tidal air, 15.
Tissue, 4.
  connective, 20.
  elastic, 9, 12.
  muscular, 13.
Tobacco, 123.
Tongue, 49, 134, 167.
Touch, 104, 134.
Trachea (trah′-kee-er), 9.
Tricuspid valve, 25.
Trigeminal nerve, 147.
Tubes (head and trunk divisible into two), 4.
Tubuli uriniferi, 100.
Tympanic membrane, 126, 127.

ULNA, 175.
Urea, 98.
Ureters, 98.
Urinary bladder, 99.
Urine, 101.
Utricle, 130.

VALVES of the heart, 25.
  in veins, 20.
  semilunar, 28.
Vegetables, 61, 63, 68, 69, 70.
Veins, 18, 20.
  accidents to, 45.
  in villi, 56.
  interlobular, 91.
  intralobular, 93.
  portal, 90.
  of stomach, 55.
  renal, 102.
  sub-lobular, 93.
Velocity of circulation, [illegible].
Venæ cavæ, 15, 93, 102.
Vena portæ, 90.
Ventricles (ven-tri-kels) of heart, [illegible].
  of brain, 142, 144.
Ventilation, 38, 39, 41, 42.
Vertebræ, 174, 176.
Vertebrated animals, 5.
Vestibule of ear, 129.
Villi, 55, 56.
Vital force, 164.
Vitreous humour, 112, [illegible].
Vocal cords, 167.
Voice, 167.
Voluntary movement, [illegible].

WALKING, 169.
Water, 35, 64, 73, 74, 75, 76, [illegible].
  on the brain, 140.
Weight of brain, 153, 155.
White corpuscles of blood, [illegible].
  nerve matter, 140, 142, [illegible].
  of the eye, 113.
Will, 143.
WILSON, Mr. Erasmus, quoted, 177.
Windows of the ear, 128, [illegible].
Windpipe, 9.
WINSLOW, Dr. F., quoted, 159.

YELLOW spot, 11[illegible].

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